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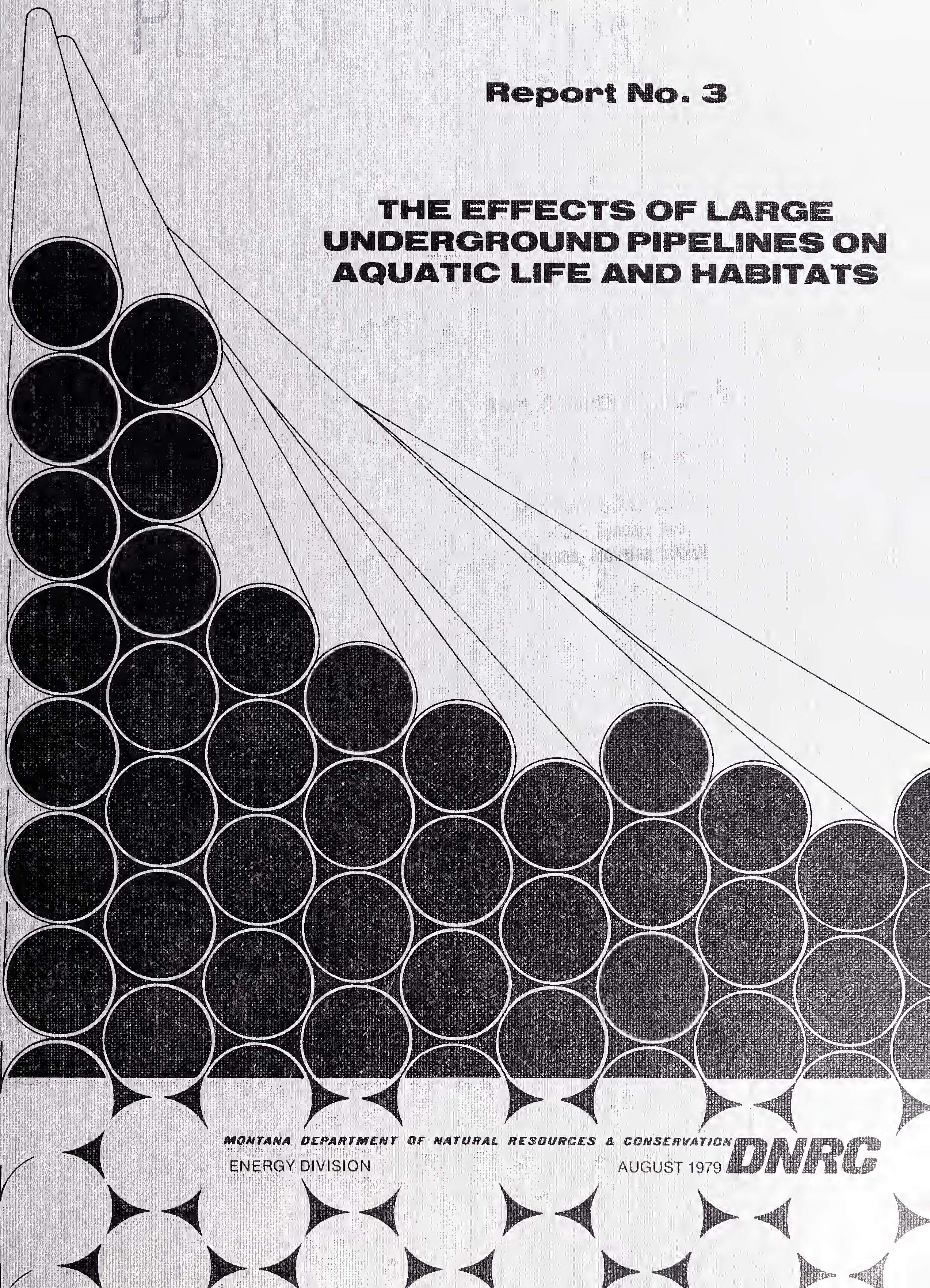
NORTHERN TIER

Report No. 3

THE EFFECTS OF LARGE UNDERGROUND PIPELINES ON AQUATIC LIFE AND HABITATS



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The Effects of Large Underground Pipelines on Aquatic Life and Habitats

ERRATA

On page 13 in paragraph 6, line 6 should read "could" instead of "would."

Also on page 13 in paragraph 6, line 9 should read "barrels" instead of "barrels/1."

On page 16 the title for table 1 should read "arctic" lakes instead of "aquatic" lakes. This change should be noted in the table of contents.

On page 32, the title for figure 3 should be: Relationship between dynamite discharge and lethal distance to fish compiled from tests on anchovies and calculated for a lower lethal limit of 40 lb/in^2. This correction of title should be noted in the table of contents also.

Northern Tier Report No. 3

THE EFFECTS OF LARGE-DIAMETER UNDERGROUND CRUDE-OIL PIPELINES ON AQUATIC LIFE & HABITATS

With Emphasis on the Proposed Northern Tier Pipeline in Montana

by
Fred Robinson, Aquatic Biologist
on contract with the Montana Department
of Natural Resources and Conservation
in consultation with
Olson-Elliott and Associates
Helena, Montana

Dave Janis, Project Manager, Northern Tier Pipeline Study
Peggy Todd and Mark Nicholson, Editors

Department of Natural Resources and Conservation
Energy Division
32 South Ewing
Helena, Montana 59601

August 1979

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ABBREVIATIONS

ADEC	Alaska Department of Environmental Conservation
b	barrel
BLM	Bureau of Land Management
bpd	barrel per day
cm	centimeter
DNRC	Department of Natural Resources and Conservation (Montana)
ft/s	foot per second
ft^3/s	cubic foot per second
gal	gallon
ha	hectare
in	inch
JFWAT	Joint Fish and Wildlife Advisory Team
km	kilometer
kV	kilovolt
m	meter
m^3	cubic meter
m/s	meter per second
mg/l	milligram per liter
NTPC	Northern Tier Pipeline Company
NTPS	Northern Tier Pipeline System
ORV	off-road vehicle
lbs/in^2	pounds per square inch
Q	discharge
TAPS	Trans-Alaska Pipeline System
USDI	United States Department of the Interior
USDOT	United States Department of Transportation

ACKNOWLEDGEMENTS

Northern Tier Pipeline Company funded study of the potential impacts of the proposed Northern Tier Pipeline on aquatic life and habitats. Information on the potential impacts was gathered by Dana Schmidt from Olson-Elliott and Associates, consultant to the Montana Department of Natural Resources and Conservation (DNRC); Charles Kay, contractor with Olson-Elliott and Associates; and Fred Robinson, aquatic biologist on contract with DNRC.

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Others from DNRC who assisted in the report's preparation include: Lee Shelton, who made metric conversions and compiled the list of abbreviations, glossary, and literature citations; Pam Goddard and Denise Thompson, who typed the manuscript; June Virag who prepared the illustrations; and D. C. Howard, who designed the cover of the report. Special thanks go to Dave Lambert for his editorial guidance, and to Gary Wolf for his assistance in preparing the report for publication.

CHAPTER ONE

INTRODUCTION

The following analysis of the effects of a large-diameter, underground pipeline on aquatics and habitats supplements the state's Draft EIS on the Proposed Northern Tier Pipeline System, prepared by the Department of Natural Resources and Conservation (DNRC). The Northern Tier Pipeline Company (NTPC) has proposed a 102- to 107-cm-diameter (40- to 42-in-diameter) underground pipeline system to transport crude oil from a tanker port at Port Angeles, Washington, to Clearbrook, Minnesota, traversing approximately 1014 km (630 mi) of Montana en route.

The state's draft EIS discusses the impacts of Northern Tier's proposed route and alternative routes. The U.S. Bureau of Land Management (BLM) has also prepared a draft EIS on the proposed project (USDI 1979).

This report (1) gives a general description of large-diameter, underground, crude oil pipelines (such as the proposed Northern Tier Pipeline System, or NTPS), (2) discusses the impacts on aquatic life and habitats from construction, operation and maintenance, and abandonment of such a pipeline, and (3) identifies ways in which adverse impacts to these resources could be avoided or prevented. While the report emphasizes effects on Montana aquatic life and habitats, the information is generally applicable to study of the impacts a large, underground pipeline would have in other parts of the country where aquatic life and habitats are similar to those in Montana.

This report is one in a series of six reports prepared in conjunction with the state's draft EIS. The series consists of the following reports:

Report 1	The Effects of Large-Diameter Underground Crude-Oil Pipelines on Soils and Vegetation, with Emphasis on the Proposed Northern Tier Pipeline in Montana
Report 2	The Effects of Large-Diameter Underground Crude-Oil Pipelines on Wildlife, with Emphasis on the Proposed Northern Tier Pipeline in Montana
Report 3	The Effects of Large-Diameter Underground Crude-Oil Pipelines on Aquatic Life and Habitats, with Emphasis on the Proposed Northern Tier Pipeline in Montana
Report 4	Earthquake Hazard to the Proposed Northern Tier Pipeline in Montana
Report 5	The Effects of Large-Diameter Underground Crude-Oil Pipelines on Land Use, with Emphasis on the Proposed Northern Tier Pipeline in Montana

Report 6 Social and Economic Impacts of the Proposed Northern Tier Pipeline in Montana

The reports are available on request from the Montana Department of Natural Resources and Conservation, Energy Division, 32 South Ewing, Helena, Montana 59601, (406) 449-3780.

CHAPTER TWO

A GENERAL DESCRIPTION OF LARGE UNDERGROUND CRUDE-OIL PIPELINES

The following is a summary of the activities typically required to construct, operate and maintain, and abandon a large-diameter, underground, crude oil pipeline system. The impacts of these activities are then discussed in the chapter of this report titled "The Effects of a Pipeline System on Aquatic Life and Habitats." More detailed discussions of pipeline system design and techniques of constructing, operating, and maintaining a pipeline are in chapters two ("Description and Justification of the Project as Proposed by NTPC") and five ("Engineering and Geotechnical Concerns") of DNRC's draft EIS.

SUMMARY OF ACTIVITIES

PIPELINE CONSTRUCTION

The construction of a large-diameter pipeline system would involve the following activities:

1) Making survey flights over the pipeline route prior to construction

2) Surveying and staking the centerline

3) Clearing vegetation from the construction right-of-way

4) Excavating the pipeline trench

5) Transporting pipe to the trench, welding pipe sections, placing them on skids, and wrapping pipe with a protective cover (pipe staging)

6) Laying the pipe and backfilling

7) Constructing crossings where a pipeline intersected rivers, streams, canals, roads, utility lines, and other pipelines

8) Testing the soundness of the pipe (hydrostatic testing)

9) Reclaiming sites disturbed by construction

CONSTRUCTION OF FACILITIES ASSOCIATED WITH A PIPELINE

Facility construction would involve:

1) Establishing work camps for construction personnel where existing housing could not accommodate an influx of workers[1]
2) Possibly, constructing access roads to the pipeline and associated facilities[2]
3) Installing drainage structures where access roads cross waterways
4) Installing high-voltage electrical transmission lines serving pump stations and delivery facilities, and low-voltage distribution lines serving valves
5) Establishing storage yards for pipe and construction materials
6) Excavating material sites (such as gravel pits)

PIPELINE OPERATION AND MAINTENANCE

The following maintenance activities would take place during operation of a pipeline system:

1) Controlling growth of vegetation within the permanent right-of-way
2) Maintaining pump stations, delivery facilities, and powerlines
3) Possibly, maintaining access roads to the pipeline, pump stations, and delivery facilities
4) Making survey flights over the right-of-way
5) Controlling, containing, and cleaning up oil spills, and reclaiming spill areas

---

[1] NTPC has stated it does not plan to establish work camps.

[2] For this report, access roads are defined as any road (including a spur road, right-of-way road, and construction traffic and passing lanes) that would be needed to reach a pipeline corridor or an existing road. Although NTPC has no plans to construct new access roads to its pipeline, new roads might be necessary with any of the alternative NTPS routes or the route of any other pipeline system that might be proposed through Montana.

PIPELINE ABANDONMENT

The following activities would occur after completion of pipeline operation:

1) Flushing oil from the pipeline with water

2) Collecting and treating the water at wastewater treatment facilities, normally constructed at discharge sites

3) Possibly, removing pipe from the trench; this would involve many of the previously mentioned construction activities, including accommodating construction workers, clearing the right-of-way, excavating the pipeline trench, and reclaiming disturbed areas

ACTIONS AND FACILITIES OF PARTICULAR CONCERN

Of the above, pipeline water crossings, access roads, drainage structures, material sites, workcamps, pump stations and delivery facilities, hydrostatic testing, mainline oil spills detection, and abandonment are of particular concern to aquatics and are discussed in more detail below.

WATER CROSSINGS

Special techniques are required for water crossings. The four major techniques of crossing rivers, streams, and canals are trenching, aerial spanning, directional drilling, and horizontal drilling.

Trenching

To facilitate trenched pipeline crossings, a wider than normal right-of-way must be cleared for the temporary storage of material excavated from the trench. The crossing pipe must be strung, bent, welded, concrete coated, and prehydrotested before any instream work begins. Then, the streambed is excavated with backhoes (see figure 1 in appendix A), draglines or dredges depending on the width of the stream, the stream flow, and streambed material. The trench is excavated to a depth beneath the natural streambed sufficient to position the top of the pipe a minimum of four feet below the maximum predicted scour depth, (see appendix G in the draft EIS.) In deep water, the machinery must be mounted on barges equipped with power winches and stabilized with winches, cables, and anchors attached to the stream bottom or the shore. The excavated material is usually placed on the stream bottom next to the trench for use as backfill after the pipe is in place. If the crossing permit requires excavated material to be replaced with select material or prohibits the instream storage of this material, the excavated material may be loaded on barges and taken to the shore for disposal or storage.

Some sand-bottom streams carrying subsurface water may be dewatered, then excavated with a dragline. Drilling and blasting may be necessary where stream bottoms are solid rock.

After excavation, the pipe must be pulled into place with rollers, floats, pulling winches and sideboom cats. Pulling pipe across rivers is a complicated procedure--a 122 cm (48 in) diameter concrete-coated pipe will weigh approximately 1490 kg/m (1,000 lbs/ft); the concreted crossing pipe sections often are 122 m (400 ft or more) long.

When the pipe is in place, the ditch must be backfilled, the river banks restored, and the area cleaned up.

Aerial Pipeline Crossing

There are three main types of aerial pipeline river crossings: (1) free span suspension bridge, (2) pier crossing, and (3) installation of pipeline on an existing highway or railroad bridge.

In construction of a suspension bridge, large towers are built on each side of the river. The areas excavated for the suspension tower footings and anchors may fill with water. This water must be continuously pumped out until the concrete footings and anchors have been constructed. The pipe is floated across the river on pontoons and raised into place. This procedure often requires riverbanks to be cut down to the waterline to facilitate moving the welded pipe across the river. The pipeline and towers are supported by a system of large-diameter steel cables attached to concrete anchors buried near the suspension towers. A pier crossing is basically a regular highway or railroad type bridge designed to support single or multiple pipelines. A pier crossing can cross a river with one span or it can be built with instream piers and multiple spans, depending on the width of the river at the crossing. Instream pier sites will have to be dammed off, excavated, and then dewatered before the concrete support pier can be constructed. This usually requires continuous pumping to allow work on the portion of the pier that is below riverbed level. Use of an existing bridge would require that the bridge had been designed to carry the extra weight that the pipeline would add. There would be minimal instream and bank disturbance.

Directional Drilling

In the directional drilling method of stream crossing installation, a drilling machine is positioned on one bank of the river. This machine arcs a tunnel under the riverbed. As the drilling proceeds, the cutting head pulls the outer casing pipe through the tunnel. This outer casing accommodates and protects the oil pipeline, which is then pulled through the casing to complete the installation. Such technology is in its infancy for large-diameter pipelines. Directional drilling at present can only be used where there is a homogenous substrate beneath the river and has not to date been used in bedrock. Also, the drill cannot be turned through too sharp an angle to get back to the surface abruptly; thus the technique is impractical on smaller streams.

Horizontal Drilling

Pits 9 to 15 m (30 to 50 ft) from the stream banks are excavated to a depth permitting the drilling of a straight line, subchannel tunnel between pits, with the tunnel crown elevation below the maximum predicted scour depth. As with directional drilling the cutting head of the drill pulls an outer casing pipe through the tunnel. The oil pipeline is then pulled through the casing pipe. Use of this method requires dewatering of the pits and the subchannel tunnel during construction. Since the drilled tunnel is in a straight line rather than an arc, the engineering difficulties are not as great as with directionally drilled crossings. Also, since this is the commonly used method for highway crossings, the technology is not as exotic as directional drilling.

ACCESS ROADS

To construct and operate a pipeline system, access to the pipeline and related facilities would be needed. In some areas, existing roads could be used; in other areas, new roads would be constructed. (See footnote 2 on page 4 for a definition of access roads.) Generally, access roads would be designed and constructed to accommodate the heaviest and widest equipment needed. Not all access roads would be permanently maintained. Those needed only for construction might not be maintained, although they could be used for surveillance during pipeline operation or for emergencies, such as oil spill cleanup. Others, such as roads to pump stations and delivery facilities and some roads to the pipeline, would be maintained for the life of a project.

The number and length of access roads required to construct and maintain a pipeline system would depend largely on the location of the pipeline and associated facilities, and on the type of construction operation employed.

DRAINAGE STRUCTURES

Construction

Streams crossed by the right-of-way, access roads, and other facilities require drainage structures that allow for the passage of both water and vehicles. The three basic types of drainage structures are culverts, bridges, and fords. Installation of culverts requires excavating the streambed to permit proper bedding of the culvert. Culverts also require inlet and outlet armoring (protection with riprap or similar material) along with fill material around the culvert. Bridge installations usually require less instream disturbance than culverts. Pilings may involve some instream work. The approaches to bridges may be stabilized with riprap or gabions. Fords are constructed by excavating unstable materials such as silts and natural organics, and replacing them with layers of more stable materials.

Determination of Drainage Discharge

It is important that discharge be accurately assessed before installation of drainage structures in order to avoid impacts on aquatic life and habitats.

A drainage structure is normally designed to pass a certain maximum runoff from its drainage area. There is little or no historic flow data for smaller streams in most areas, however. For these streams, the size of a drainage structure for a particular drainage basin can be chosen on the basis of a discharge formula. These empirical formulas usually are based on the size of the drainage area involved, the maximum intensity of rainfall, and the geographic region in which the drainage area is located. The formulas usually include a constant which is intended to compensate for watershed slope and shape. Empirical results obtained by these equations are used in other formulas to calculate those maximum runoff conditions which might be expected to occur once every five, ten, fifty or one hundred years (McKinley and Webb 1956). The size of the drainage structure is then determined for a particular stream on the basis of government specifications and company demands. For instance, on the Trans-Alaska Pipeline System (TAPS) all temporary drainage structures were designed to pass the five-year flood (Q_5) and all permanent drainage structures were to be constructed to pass the fifty-year flood (Q_{50}). Regulations on fish streams often require drainage structures to pass the Q_5 at a specific water velocity. On TAPS, government biologists recommended in the agreement and right-of-way grant for TAPS (1974) that all drainage structures on fish streams should be designed to pass the Q_5 at less than 1.2m/sec (4 ft/sec) to permit uninterrupted movement and safe passage of fish (MacPhee and Watts 1975). In the past, discharge calculations have often been too low. Therefore, these drainage structures were undersized for the actual stream discharge and many were inadequate to pass even normal high water flows.

MATERIAL SITES

Pipelines require bedding with such material as gravel in rocky areas, and demand may exceed the capacity of existing commercial sources. Therefore, new sites would be developed. Such materials are often most readily available in flood plains.

WORK CAMPS

In remote areas where there would not be enough housing to accommodate an influx of construction workers and supervisory personnel, temporary housing may be constructed. The size of a camp would vary according to the pipeline work schedule and existing housing in the vicinity. Housing units may be necessary for pipeline workers in areas where other lodging is unavailable. (NTPC currently does not propose any work camps in Montana.)

PUMP STATIONS AND DELIVERY FACILITIES

Mainline pump stations increase pipeline pressure and maintain the desired flow of crude oil through the line. The pump units boost the pressure in the pipe to overcome elevation differences and friction.

The pump station's major equipment and facilities generally consist of: electrically driven centrifugal pump units, a surge relief tank, launchers and receivers for pipeline cleaning equipment, strainers, a drain system, valving, pressure control valves, piping, a control building, a high-voltage electrical supply, transformers, a communications tower, heliport, access road, lighting, an emergency generator, and fencing. Facilities and equipment of pressure reducing stations are similar to those of pump stations. Pump stations for a large-diameter pipeline would require about 2 to 2.8 ha (5 to 7 acres) of land (NTPC 1978).

Pump stations receive electrical power via overhead transmission lines, which usually vary in size from 69 to 230 kV, depending on the horsepower requirements of facilities and the voltage available (USDI 1979).

At delivery stations, consignments are received and delivered to connecting pipeline systems. Facilities could include large storage tanks, a pump station, and oil-water separation ponds. Delivery sites may require 24 ha (60 acres) of land (NTPC 1978).

Pump stations and delivery facilities both require permanent, all-weather access roads and are generally illuminated at night for maintenance and security.

HYDROSTATIC TESTING

Hydrostatic testing is required by the federal government to test the soundness of the pipeline. For hydrotesting, a pipeline is divided into test segments based on pipe wall thickness, nearness to pump station, hydraulic pressure, and the design operating pressure of that portion of the pipeline; the length of the test sections depends on the uniformity of the pipeline diameter. In mountainous areas, test sections may be as short as two to five miles, or upwards of twenty miles in less severe terrain. An adequate water source is required for all hydrostatic testing; 1.0 m^3/m (82 gal/ft) are required to fill a 102-cm-diameter, (40-in-diameter) pipeline.

Pumps are positioned at the edge of a watercourse to withdraw the test water. In the winter methanol or antifreeze may be added to the water, or the water may be heated. A bactericide or soda ash may be added to the water for rust control. Water is pumped into the line to a pressure 25 percent above the maximum designed operating pressure. Hydrostatic test pressure must be maintained for a continuous twenty-four hour period.

A leak in the pipeline is indicated if water has to be continuously added during the hydrotest to maintain the required hydrostatic pressure. If the hydrostatic test pressure drops abruptly the pipeline has ruptured.

If a portion of the pipeline fails during testing, the defective portion must be replaced and the test section retested until it is satisfactory. After a successful hydrotest, the water is discharged. Because of the large volumes of water and the pressures involved, energy dissipation devices and/or settling ponds may be required at the discharge point. This water may require treatment.

MAINLINE OIL SPILL DETECTION

Large spills would be automatically detected by instruments at pump stations that measured deviations in the pressure and volume of flow. Spills too small to be detected automatically would be discovered during aerial surveillance (which would take place about once every two weeks) or by observation by pipeline employees or the public. If a spill report were based on detection by instruments rather than direct observation, the exact location of the leak would not be known--all that would be known is that the leak was somewhere between two pump stations. Personnel and equipment for containing and cleaning up a spill might not reach a spill until several days after its discovery. A difficult case would result if a pipeline leak, below the minimum automatic detectable level, were to occur under the ice. Oil could leak into the water course for weeks, undetected. The total volume of such a spill could be substantial if it remained undetected and could be larger than would occur from a complete pipeline rupture. This is a disadvantage of any subsurface crossing technique in cold environments.

POST-OPERATION ABANDONMENT

When pipeline operation ends, water is used to flush oil from a pipeline; the water is then collected and treated at a wastewater treatment facility, which would normally be constructed at the discharge site.

The entire length of the pipeline may be dug up to reclaim the pipe. It is estimated that a mile of 107-cm (42-in) diameter pipe contains approximately 417,300 kg (460 tons) of steel. Pipeline removal would entail many of the previously-described construction activities, including construction of access roads, right-of-way clearing, excavating, grading, and an influx of people.

CHAPTER THREE

EFFECTS OF A PIPELINE SYSTEM ON AQUATIC LIFE AND HABITATS

PETROLEUM POLLUTION

SOURCES

Petroleum pollution in waterways due to a crude oil pipeline can occur during construction, testing, operation, and abandonment of the pipeline. The following section discusses sources of spills.

Construction-Related Oil Spills

When construction equipment is operated near water, there is an increased probability that construction-related oil spills will enter flowing water and affect aquatic resources. This was a chronic problem during construction of the TAPS (Kavanaugh and Townsend 1977).

The amounts of oil spilled during construction of a pipeline can be considerable. Reported volumes of petroleum spilled during construction of TAPS totaled 2,025 m^3 (535,000 gal) (Alaska Department of Environmental Conservation [ADEC] 1977). The extent of damages to aquatic resources caused by such spills would depend on their reaching of waterways. Some may flow directly into waterways; some may be washed in later by rainstorms. The causes and sources of these spills are numerous:

1) Leakage of oil or hydraulic fluid from defective machinery can be a chronic problem, resulting in numerous spills, usually less than .20 m^3 (50 gal). Hydraulic lines can easily rupture, particularly during extreme cold.

2) Careless refueling can result in oil spills when fuelers place the fuel hose in a vehicle's tank, turn the nozzle on, and walk away. If the fuel hose's shut-off valve fails to perform properly, the tank will overflow. This type of problem can be particularly serious when tankers are filling large fuel tanks. The latter case resulted in several spills of 20 m^3 to 30 m^3 (5,000 to 8,000 gal) on the TAPS (ADEC 1977).

3) Equipment often overturns during large construction projects. An overturned pickup may leak from .08 m^3 to .20 m^3 (20 to 50 gal), a semi-truck, dump truck, or crawler tractor from .40 m^3 to .80 m^3 (100 to 200 gal), scrapers from .80 m^3 to 1 m^3 (200 to 300 gal), and a small right-of-way fuel truck from 4 m^3 to 20 m^3 (1,000 to 5,000 gal). Less frequent occurrences, but more critical, are spills caused by overturned tank trucks with capacities of 30 m^3 to 38 m^3 (8,000 to 10,000 gal).

4) Fuel bladders used for storage sometimes develop small punctures or can rupture suddenly. Metal tanks present less of a problem.

5) Leaks can occur in heating fuel lines at construction camps. On the TAPS several of these went undetected for weeks because of snow cover and subsurface flow and were estimated at over 380 m^3 (100,000 gal) or more for each spill (Kavanaugh and Townsend 1977, ADEC 1977).

6) Negligent workers may let used oil drain on the right-of-way during oil changes. Minor oil spills on the right-of-way, though small in volume, are frequent; cumulatively they can have a major impact on the environment. From 1974 to 1976, 11,295 minor oil spills, totaling 286 m^3 (75,526 gal), were officially reported on the Alaskan pipeline (ADEC 1977). However, federal surveillance personnel who continuously monitored construction of the TAPS estimated that only 25 percent of the minor oil spills were officially reported as required. If this estimate is accurate, there were actually over 40,000 minor oil spills totaling 1,100 m^3 (300,000 gal) during construction of the TAPS.

Hydrostatic Test Water Discharge

The internal mandril of the pipe bending machine used for shaping the pipe to the trench is hydraulically operated and is subject to leaks. The internal surface of the pipe can become coated with oil which is flushed out when hydrotesting is done. During discharge of the Tanana River hydrotest on TAPS (Hughes 1976), leaks in hydraulic lines resulted in concentrations of 56.9 mg/l oil in the latter portions of discharged hydrotest water; concentrations of 2.3 mg/l oil occurred in mid-discharge water.

Mainline Oil Spills

Minor oil spills may result from leaking valves or gauges, oil losses at scraper traps or separators, or similar occurrences. Larger spills may result from pipeline splits or ruptures caused by operational error, defective pipe, imperfect welds, pipe corrosion, landslides, vandalism, sabotage, excavation equipment hitting the pipe, river scour, and earthquakes.

An examination of the Department of Transportation statistics for oil spills for the 1977 calendar year (USDOT 1978) indicates the average oil spill size from crude oil lines is 108 m^3 (28,560 gal), with the maximum recorded of 1,700 m^3 (441,000 gal). The maximum loss of oil from the proposed Northern Tier Pipeline at river crossings in Montana could be as high as 1,800 m^3 (483,000 gal) (USDI 1979). The probability that such spills may occur is examined in Montana's draft EIS of the Northern Tier Pipeline. Any predictions as to frequency of occurrence are speculative due to lack of relevant data. USDI's data would indicate the probability to be quite low .0014/km/yr (.0022/mi/yr). It should be pointed out, however, that four major spills occurred in the first month of operations of the TAPS.

Mainline oil spills at river crossing sites or in flood plains are likely to reach waterways.

Abandonment

Water used to flush out the abandoned pipe picks up large quantities of oil. The law requires this water to be treated before discharge back into waterways.

EFFECTS

Petroleum products could harm aquatic organisms in the following ways: (1) oil may act on the body and gill surfaces of fish and invertebrates and interfere with respiration, (2) oil may coat and destroy algae and other plankton, (3) settling oil may coat the lake or stream bottoms, destroying bottom organisms and interferring with spawning areas, (4) decomposition of oil by microorganisms may deoxygenate the water, (5) heavy coatings of oil on the water surface may interfere with photosynthesis or prevent reoxygenation of the water, and (6) soluble fractions of the petroleum product may have toxic effects on aquatic organisms. In addition, oil may be ingested by fish and taint the flavor of the flesh.

The basic chemical and physical properties of crude oil or other petroleum products bear directly on the severity of impacts expected from oil spills. Certain components of crude oil, primarily the lighter-weight aromatic compounds, contribute significantly to the toxicity of oil to aquatic organisms. These components are highly volatile, however, and may be soluble in water, reducing the duration of toxicity. The heavier compounds are more persistant and cause impacts other than direct toxicity.

Alaska crude oil has a high aromatic content which causes its immediate toxicity to be quite high. Toxicity studies of Rice et al. (1975) indicate that even low concentrations of oil in the water would be highly toxic to late alevin or emergent pink salmon fry as the researchers found 50 percent mortality of these life stages after ninety-six hours of exposure to a concentration of 0.4 ml/l Prudhoe Bay crude oil (in other words the 96-hr LD50 is 0.4 ml/l). Low concentrations of oil (less than .075 ml/l) had adverse effects on growth of young salmonids, indicating that even low doses may have an overall long-term effect on their survival. Oil was also toxic to eggs; concentrations of 3.2 ml/l produced about 50 percent mortality after ninety-six hours.

The rate of oil escape into the stream is more important than spill volume in determining the concentration of oil in that stream. The minimum amount of oil loss that the proposed Northern Tier Pipeline's leak detection system will record is approximately 550 m^3/d (3,500 bpd). Based on the 0.4 ml/l LD50 (Rice et al. 1975) for salmon fry from Alaska's Prudhoe Bay oil, such spills would result in lethal oil concentrations in streams with flow volumes up to 16 m^3/s (570 ft^3/s). Calculated maximum volumes of oil occurring at river crossings of the proposed Northern Tier Pipeline average around 1,600 m^3 (10,000 barrels/l) (USDI 1977). If such a spill were allowed one hour to leave the pipeline and enter the river, oil concentrations lethal to salmonids would be produced in rivers of flow volumes up to 916 m^3/s (32,500 ft^3/s). This conclusion is again based on the 0.4 ml/l LD50 found by Rice et al. (1975).

Studies on oil spills effects on warm-water species have dealt with diesel fuel spills from tank trucks. Although these findings are not directly applicable to major pipeline-connected oil spills, they do indicate the effects of diesel fuel spills related to pipeline construction. A study of a spill of 26,000 l (7,000 gal) of diesel fuel on Boone Creek in South Carolina (flow = .1 m^3/s, or 4 ft^3/s) indicated 90 percent mortality of sucker (Catostomidae) and minnow (Cyprinidae) species in the 305 m (1,000 ft) of stream below the spill (Schultz and Tebo 1975). Because these species often are the most resistant to pollutants, more severe effects could be expected on game species.

An extensive kill of fish, reptiles, and amphibians was observed over a 4-km (2.5-mi) section of stream after several thousand gallons of diesel fuel spilled into a trout stream in northern California (Bury 1972). Most animals were adversely affected one to four days after the fuel entered the study area.

McCauley (1964), examined the effect of oil pollution on organisms other than fish in Muddy River, Massachusetts. She concluded the following:

> The toxic effect of the oil was pronounced on the macrofauna of the bottom sediments and plankton organisms. In the bottom sediments Gammarus, Agrion nymphs, and Dugesis were unable to tolerate conditions in the region of oil pollution while Tubifex, Tendipes larvae, Nemata and Hirudinea types were tolerant and survived.
>
> Spirulina, Volvox, Chilomonas, and Arcella were completely intolerant to oil conditions in the water. The following plankters were tolerant of oil pollution surviving during the period of highest oil concentration: Lyngbya, Oscillatoria, Ankistrodesmus, Chlamydomonas, Closterium, Gonium, Scenedesmus, Asterionella, Cyclotella, Fragilaria, Meridion, Navicula, Tabellaria, Euglena, Trachelomonas, Vorticella, Asplanchna, Keratella, Polyarthra, and Cyclops.

Lakes and reservoirs receiving oil from pipeline leaks will generally be easier to clean up than streams, except during high winds on large water bodies; because of reduced mixing of oil with the water, fisheries would not be affected as severely. However, experimental oil spills on subarctic lakes indicated that the benthic invertebrate communities represented by Trichopterans, Plecopterans, and certain groups of the Chironomidae were affected (Snow and Rosenberg 1975).

Effects of spilled oil on fish taste occur at low oil concentrations. Taste-tainting of fish flesh has been shown to occur with 9.8 l (2.6 gal) of outboard motor oil and gasoline per acre-foot of water (Surber et al. 1975), demonstrating the need for concern over small construction-related spills.

FATE AND DISTRIBUTION OF SPILLED OIL

The fate of oil in the aquatic environment is difficult to assess. It is dependent upon location of containment basins, volume of the spill and rate of entry into the stream, streamflow, stream gradient, season and location of the spill, type of stream bottom, natural degradation processes, and effectiveness of cleanup.

The most difficult cleanup of oil in aquatic environments would be in fast-moving, mountain streams. Slower moving prairie streams also would present some cleanup difficulty. Lakes and reservoirs will generally be easier to clean up than running water. Oil spills underground in floodplains are difficult to detect and clean up and could continue to drain into streams for some time.

Information on crude oil toxicity indicates that the fraction which produces the most direct toxicity to aquatic life also dissipates most rapidly by evaporation or other natural degradation processes. Although this means that long-term direct toxic effects probably will not occur, little could be done to prevent immediate toxic effects, regardless of the proposed cleanup procedures. The heavier carbon fractions of the crude oil would produce longer-term impacts, with severity dependent upon effectiveness of cleanup methods, and natural degradation and flushing.

The relative degradation-dissipation time of crude oil is represented in Table 1 (Snow and Scott 1975), based on oil distributed experimentally over water in arctic lakes. More rapid decomposition would occur in warmer water (McCauley 1964). Streams would show relatively faster degradation because of the agitation of the oil. This shorter duration would be of small consequence as many more miles of shoreline (streambank) would be affected in a stream than on still water, and oil would be difficult to effectively clean up in a stream. The agitation in the higher gradient streams would result in stream bottoms becoming contaminated with the oil, resulting in more toxicity to the aquatic life than would an oil slick on a lake or reservoir.

Information on the natural rate of removal of oil from different types of stream bottoms and stream bank areas is scarce. Large rocks may become coated with oil but will be cleaned through turbulence in a short period. Fine sediments or organic material may mix with oil and form a long lasting mat. Diesel fuel spilled on Boone Creek in the southeastern United States was still detectable as a sheen on the water nine months after the spill (Schultz and Tebo 1975). Thirteen months after this same spill, the sediment contained hydrocarbon concentrations. Experimental oil spills on lakes in Northern Canada (Snow and Rosenberg 1975) indicated that oil concentrations in shore sediments returned to near normal background after 15 months, primarily because of oil removal by spring flooding. Studies on a small stream (Snow et al. 1975) with a small experimental oil spill 250 l (66 gal) of oil indicated drastic immediate reductions of invertebrate populations, but there was complete recovery and no detectable oil after one year. In actual spills such as the 20,000 l (5,284 gal) of aviation fuel documented by Bugbee and Walter (1972), residue and decreased diversity of aquatic invertebrate communities could still be detected two years after the spill. The most obvious conclusion from these studies is that a comparatively small amount of petroleum products is extremely toxic. The relative recovery rates of affected biological systems depends on the volume and rate of the spill, the volume of receiving water to dilute the oil, and several other factors.

TABLE 1. Relative degradation of crude oil on aquatic lakes.

Hours After Spill	Percentage Remaining by Crude Oil Type	
	Pembina	Norman Wells
1		73
2	74	
16	70	
24		64
48	61	
60	55	51
72		48

SOURCE: Snow and Scott 1975.

[a] All portions of the oil below a 9 carbon chain evaporated in the first two hours of exposure.

SEDIMENTATION

SOURCES

Sources of sediment that may be released in aquatic systems due to pipeline construction are many. The following sections will discuss some of those sources.

Trenched River Crossings

Trenching across streambeds releases large amounts of buried sediment. The amount, transport, and deposition of sediments is greatly influenced by streambed and subbed material, stream morphology and other hydrological factors.

Water quality tests during the installation of the Salcha crossing of the TAPS line in Alaska gave the following results:

> During the 17 days of construction, an estimated total suspended sediment load of 11 tons passed Station 1 470 ft above the pipeline crossing. Calculated sediment loads at 450 and 1,450 ft below the pipe were 829 and 481 tons, respectively. By subtracting the above-pipe concentration of 11 tons from these two figures, values of 818 tons and 470 tons of sediment

passed Stations 2 (450 ft downstream) and 3 (1,450 ft downstream). If it can be said that an equal amount of sediment dropped out of the suspension between the pipe and Station 2 as did between Stations 2 and 3 (348 tons), then at least 1,166 tons of suspended sediment were introduced to the Salcha during the seventeen days of pipeline installation (Francisco and Dinneford 1977).

For a given river, greater flow volumes have an ability to transport greater amounts of sediment. In this regard it should be emphasized that the Salcha River buried pipeline crossing was installed during the winter when the flow was 2.8 m^3/s (100 ft^3/s). If the Salcha River pipeline crossing had been installed during the summer when flows were higher, construction would have generated more sediment and washed that sediment further downstream. The Salcha's riverbed at the TAPS pipeline crossing is composed of large cobbles and gravels with little sand or silt, although there was some of this material in the subbed. Because of the low flow volume and the nature of the streambed material, the TAPS Salcha River crossing data probably represent minimum sediment generation caused by the conventional trenched method of pipeline construction.

Other results of the Salcha River crossing investigation are shown in table 2. It is evident that sediments released during trenched crossings can be carried a considerable distance, 13 km (8 mi) in that case.

Table 2. Range of suspended sediment loads during crossing at sites below Salcha Crossing[a] (TAPS).

Distance from Salcha River Crossing	Jackson Turbidity Units	Suspended Sediment (mg/1)
470 feet above	1-4	1-2
450 feet below	6-200	10-648
1,450 feet below	5-180	5-564
1 mile below	37-58	60-115
1 1/2 miles below	21-58	25-115
3 miles below	20-44	14-78
8 miles below	17-32	7-50

CONVERSIONS: 1 ft = .3048 m
1 mi = 1.609 km

[a] The low values in the turbidity and suspended sediment data collected during the Salcha Crossing installation correlate with periods of construction inactivity. High values indicate active instream work (Francisco and Dinneford 1977).

Other results showing high sediment loads were obtained during construction of other trenched river crossings of TAPS (Sloan 1975, Kernofle 1975, Townsend 1975).

Sediment generation at river crossings is also related to the amount of streambed material that must be excavated in constructing the river crossing pipe ditch. The more instream digging and the longer the digging time, the more sediment is generated. In this regard, the natural repose angle of streambed material must be considered. Trenches normally will not have vertical walls. In addition, instream storage of ditch spoil greatly increases the amount of sediment generated during river crossing construction. Spoil piles in the river also restrict the streamflow, which in turn increases the amount of stream bottom material washed into the excavated pipe ditch. This additional material must then be removed from the once excavated ditch before the crossing pipe can be pulled into place. These circumstances greatly increase the amount of sediments which will affect the downstream aquatic communities.

In most cases, spring runoff will "flush" water systems of these sediments. Streams with very low gradients, however, may require more than one season to flush out the sediments released by trenching.

Other River Crossing Techniques

Other crossing techniques which can also release sediments into streams are discussed below.

If riverbanks have to be cut down for aerial suspension bridges some sediment will enter the river, though not in the quantities associated with trenched river crossings. In addition, water pumped out of tower and anchor footing sites will be silt-laden. If this water is pumped directly into the stream, sediment impacts are possible.

Pier bridges also disrupt banks and would add sediment to the river. If there are any instream piers, excavating pier sites would release buried sediments into the stream. Pier bridges using instream piers would probably create greater sediment problems than aerial suspension bridges because of the instream excavation involved.

Horizontally drilled crossings would not involve instream excavation or bank disruption. However, water pumped out of pits and the subchannel tunnel would be silt-laden. If this water were pumped directly back into the waterway; sediment impacts could occur.

Drainage Structures

Culvert installation and ford construction with the associated streambed excavation can cause extensive siltation (Kay 1976). Construction of instream pilings for bridges would release some sediment. The approaches to all these structures may involve cutting down the stream bank, which could add sediment to the stream.

Workpads, rights-of-way, or access roads often are washed out because of inadequately-sized or blocked drainage structures (see figure 2, appendix A). Washouts cause siltation in the water and instream deposition of the eroded material. It should be mentioned that fords did not solve this problem on TAPS (Gustason 1977).

Fill material around culverts can slump causing siltation and blocking the culvert (see figure 3, appendix A). Downstream sedimentation from fords can occur when they fail under heavy vehicular traffic. Ruts can form in fords and silt can wash out continuously.

Access Roads

The building of access and maintenance roads, particularly if they are in steep mountainous areas with unstable soils, provides a high risk for increased sediment output, and may ultimately result in the direct disturbance of a much larger area than is involved in the actual pipeline right-of-way.

Soil mass movement and landslide erosion, both of which are commonly associated with road building in steep areas, have been identified as a major source of sediment introduction into aquatic systems (Fredricksen 1965, Swanston 1970). Studies have also shown that sediment deposition in areas where no timber removal took place, but where roads were constructed, was as high as when logging followed road construction (Megahan and Kidd 1972).

The movement to and from the construction sites by large, heavy equipment involved in construction can result in breakdown and damage to existing and new access roads. As a result, erosion is increased in areas of steep slope and unstable soils, and is compounded by road use during wet conditions. Inadequate road construction is also a primary source of road failure. A further problem results when vehicle traffic in dry periods raises dust which settles in water bodies.

Material Sites

Excavation of material sites adjacent to streams could add large amounts of sediment to those streams. Large excavations can alter hydraulics of the nearby stream and a channel change can result, with the stream entering the material site and washing sediments downstream.

Buried Pipeline Construction in Areas of High Water Tables

Because of the high water table in flood plains, silty water often fills the pipeline ditch, requiring pumping or other means of removal before the pipeline can be put in place. Silty water pumped directly into a waterway can produce adverse siltation effects.

Hydrostatic Testing

If vegetated banks above water level are cut down to facilitate pump placement or if a sump is dug at the intake point (both were done on the TAPS), siltation would result.

Discharged water is also a source of problems. Dispersion on either land or water could create disturbance. If the water were discharged onto land, there could be a high potential for erosion (see figure 4 in appendix A.) If discharge rates into water are high relative to streamflow, the increased stream velocity can also produce erosion. Erosion induced by hydrotest can increase sedimentation in streams.

Cleared Right-of-Way

Clearing of vegetation from steep slopes with unstable soils or along stream channels can lead to increased erosion and sediment transport with a risk for subsequent introduction into nearby stream systems. Rainstorms during construction and before reclamation could be particularly damaging. Dust created during construction would also enter nearby waterways.

In a study of pipeline routes in Michigan, off-road vehicle (ORV) use of rights-of-way was a source of continuing impacts to aquatic resources along pipeline routes (Crabtree et al. 1978). Such use causes stream widening due to destruction of stable stream banks and can prevent vegetation from reestablishing itself at such places. Also, off-road vehicle paths on slopes leading to streams are a constant source of sediment. The Crabtree study found that fish habitat was rarely as productive in any right-of-way where ORV use was heavy.

Maintenance vehicles could cause many of these same impacts. Use of the right-of-way when wet is especially damaging.

Post Operation Abandonment

The sources of sediment during abandonment of the pipeline would be largely the same as during construction, if the pipeline were dug up and removed.

EFFECTS

Effects of sediment on aquatic biota normally are more severe immediately downstream from river crossing sites, although additional sediment loads caused by increased bank erosion, runoff from unstable construction sites, and downstream movement of finer sediments could have a less apparent but long-term effect on aquatic biota. Sediments will be washed downstream for several years, eventually settling in places such as reservoirs.

Sedimentation can affect three major aquatic ecosystem components: primary producers (plankton and periphyton), invertebrates, and fish.

Primary Production

Primary production (photosynthesis) is affected by (1) reduction of light penetration, (2) scouring of algae from substrate and (3) covering of substrate by deposition of silt. These effects are most detrimental where lack of long-term stabilization of river crossings or surface areas causes a continuing increased background turbidity of waterways. A significant reduction in population of the primary producers would result in decreased growth of those higher organisms which feed upon them.

Invertebrates

Among the major causes of aquatic invertebrate mortality associated with sediment introduction are: (1) abrasive action of sediment, (2) clogging of delicate external gill systems by suspended sediment, (3) egg mortality, and (4) smothering of relatively nonmotile species by the deposition of sediment. If the mortality is great enough to represent a major loss of the food supply to the fish present in the stream, the productivity of resident fish populations may be affected (Bjornn et al. 1974, Ellis and Gowing 1957, Tebo 1955). Sedimentation effects on invertebrate populations have been well documented under experimental and natural situations (Smith 1939, Gammon 1970). Gammon (1970) established that a 40 mg/l increase in suspended solids reduced macroinvertebrate populations by 25 percent. An increase of 120 mg/l resulted in a 60 percent reduction.

The introduction of sediment into small mountain streams has been known to cause a reduction of the species diversity and density of important trout-food organisms along those areas affected. These reductions, if extensive enough, could cause a displacement of fish inhabiting these areas (Bjornn et al. 1974).

Alteration or elimination of aquatic invertebrate populations, involving both displacement and direct mortality, can be caused by substrate alteration as a result of sedimentation and is well documented. The extent of change or population alteration is dependent upon many variables, including presedimentation population levels and substrate condition (Cordone and Kelly 1961, Tebo 1955). Studies have shown that rubble is the most productive substrate for bottom organisms desirable as food sources for fish populations. When stream conditions permit the accumulation of sediment and/or silt, the interstices of rubble substrate are filled. Those forms more adapted to the sediment habitat become established, replacing forms that are a source of food for fish. The new forms are generally burrowing in habit, of smaller size, and less accessible as a food supply for fish than those forms typifying the nonsedimented habitats.

Most authors agree that if sedimentation is short-term, localized, and not excessive, aquatic invertebrate populations will return to the presedimentation densities and diversities through recolonization of the affected area by immigration of populations from unaffected upstream areas. It is doubtful, however, that rapid recovery would occur if an entire watershed were subject to the effects of excessive sedimentation (Bjornn et al. 1974, Hynes 1970, Cordone and Kelly 1961, Tebo 1955).

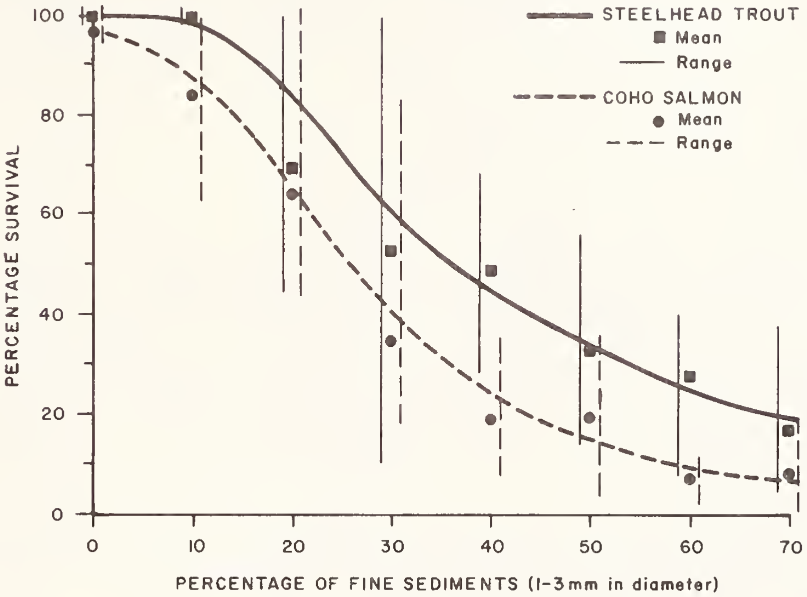
Fish

Suspended sediment can affect fish directly by reducing visibility, (thus limiting the ability of the fish to locate food sources), clogging of gills by particulate matter, and abrading external structures by the action of suspended mineral solids (Phillips 1970, Chapman 1962). The extent and magnitude of these impacts are dependent upon a number of variables, including the species, age, and general health of the fish affected, the quality of water other than sediment, the length of exposure to the sediment, and sediment particle size, shape, hardness, and frequency of introduction.

Study results vary but they do show that sediment in suspension can kill fish. Rainbow trout fingerlings live-caged in turbidities of 1,000 mg/l to 2,500 mg/l suffered 57 percent mortality in twenty days compared to only 9.5 percent mortality in a control group live-caged in clear water (Campbell 1954). Herbert and Merkins (1961) found concentrations of kaolin and diatomeceous earth as low as 270 mg/l to 810 mg/l were lethal to rainbow trout after an exposure of 10 days. Fish species most adversely affected are the salmonids, but other fish species also suffer from high levels of sediment in streams. Lethal concentrations of montmorillonite clay ranged from 52,000 to 150,000 mg/l at an average exposure of seven and one-half days for largemouth bass, and 80,000 to 225,000 mg/l at an average exposure of five and one-half days for green sunfish (Wallen 1951). In general, suspended sediment concentrations must exceed 200 to 300 mg/l for many days before direct mortality results (Phillips 1970).

In most cases, indirect damage to the fish population through destruction of the food supply, eggs or larval stages, displacement due to avoidance reactions of the fish, or changes in the habitat probably occur long before the adult fish are directly harmed. Mortality of fish eggs caused by sedimentation is well documented (Elser and Marcoux 1972, Saunders and Smith 1965, Bianchi 1963). Clean permeable gravels provide the nursery areas for fish embryos in the stream environment. Settling sediment in the water during the incubation period can greatly affect the survival rate of developing embryos by clogging the pore spaces between the gravels (figure 1). Consequently, the intragravel flow that supplies oxygen to eggs and flushes out metabolites (carbon dioxide and ammonia) diminishes, resulting in high embryo mortality (Peters 1967). Instances of high egg mortality associated with increased silting have also been recorded for species of fish which lay their eggs on surfaces, for example, yellow perch (Munoy 1962). After hatching, accumulated sediment can be harmful as a physical barrier, trapping fry and preventing them from emerging (Koski 1966, Hall and Lantz 1969). The combined effect on survival is shown in figure 2. Also, fry depend on the crevices and interstices in the gravel along the stream bottom for cover and security from predators. An accumulation of sediment can fill these spaces, eliminating escape cover. Phillips (1970) suggests that this increased vulnerability to predators may contribute to increased fry mortality. Fish are repelled by instream disturbance and may avoid high levels of suspended solids. Shallock (1979) documented the movement of salmonids out of a pipeline stream crossing area. Gammon (1970) documented the movement of various warm water species (particularly carpsuckers and smallmouth bass) out of an area below a quarry in response to increased sediments. It has also been documented that spawning fish

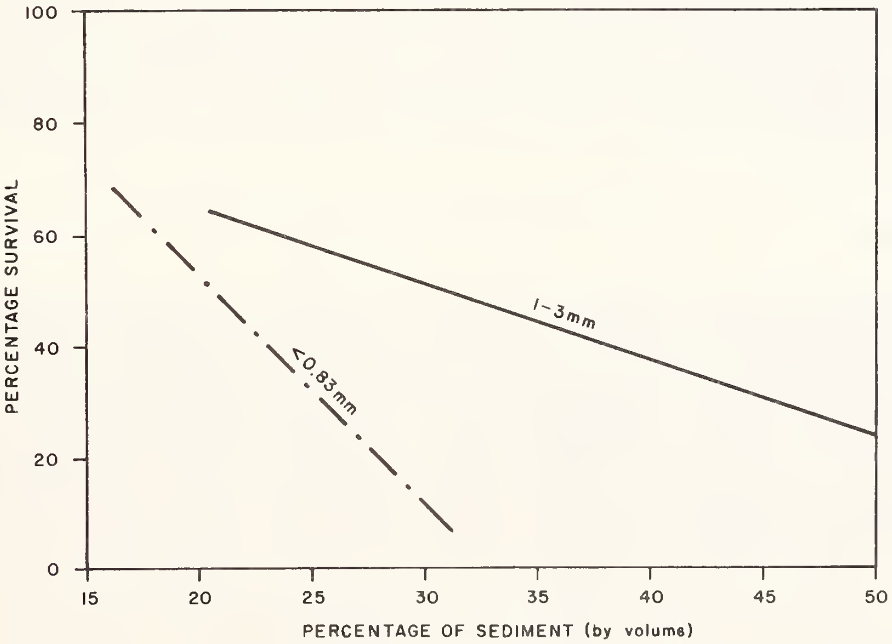
FIGURE 1. Emergent ability of coho salmon and steelhead trout fry.



SOURCE: Hall and Lantz 1969.

[a]Relation between amount of fine particles in an artificial gravel bed and the ability of coho salmon and steelhead trout fry to emerge through the gravel.

FIGURE 2. Emergent survival of coho salmon and cutthroat trout fry.



[a] Combined effect of 0.83 mm particles together with dissolved oxygen and perhaps other factors. In the 1 to 3 mm relation, dissolved oxygen was high and other adverse effects were minimized or absent.

generally avoid heavily silted waters, and are prevented from successfully spawning if a tributary stream is carrying a heavy suspended sediment load (Smith 1939). Stream morphology can be an important limiting factor to fish productivity. Adult fish populations can be seriously affected when sediment accumulation fills important pool areas reducing available cover and hiding places (Saunders and Smith 1965). Bjornn et al. (1974), working in Idaho, concluded that the summer, and probably the winter, capacity of small mountain streams where most trout reside in pools will be reduced if sufficient sediment is added to a stream to reduce pool area or volume.

Substrate alteration caused by sedimentation will, for the most part, be short-term, occurring during and immediately after the construction activities. However, if the physical characteristics of a stream limit the ability for natural seasonal sediment removal through the normal flushing action of spring flows, substrate alteration has the potential for a longer duration. Gammon's (1970) investigations reveal that population depressions continue for several years in river sections severely affected by sediment.

Increased sediment loads in waterways due to activities of man, such as agriculture, has already decreased the distribution of many North American fish species (Scott and Crossman 1973).

CHANNEL AND STREAMBED ALTERATION

Streams develop a delicate balance between width, depth, velocity, gradient, sediment load, size of sediment debris, roughness of the channel, and discharge. The interrelationships among these variables are complex, but a change in one will lead to an adjusted change in the others. Also, any upset in the balance can lead to accelerated erosion or deposition creating sedimentation problems as the stream adjusts. Construction activities in the stream and on the banks could easily upset a stream's equilibrium. Stream organisms are adapted to the existing balance in the stream and will be affected by an upset of that balance. The following sections discuss some possibilities.

CHANNELIZATION

Channelization of large or small streams is usually harmful to aquatic habitats. Such channelization could occur where channel straightening is necessary to accommodate a pipeline spread, material sites, or structures related to access roads. Channelizations often require the use of river training structures such as dikes and revetments. The cutting off of stream loops or meanders increases the gradient and therefore, the water velocity in the resultant channel. Also, water velocities are usually higher through entrained (diked) channels than through channels with natural banks. The stream loses length and fish habitat. Fish population decreases in excess of 50 percent are typical in the channelized section. The invertebrate species composition will change as a result of the increased velocities (Hynes 1970). The increased water velocities can also increase erosion of banks and streambeds within the channelized section and farther downstream. Sedimentation problems can result. In Montana, adverse effects of channelization resulting from highway construction have been reported by Holton (1960), Bailey (1957), Alford and Peters (1963), Bishop (1962), and Elser (1970). Because of the degree of damage they can cause, channelizations are regulated by state and federal laws.

DRAINAGE STRUCTURES

Long-term hydrogeologic changes can be induced by drainage structures, especially if those structures are undersized or partially or completely blocked by ice, debris, or beaver dams. Culverts can be crushed when improperly bedded or insufficiently covered, and may also be misaligned. Water tends to pond above such structures, reducing water velocity and lowering the stream's ability to carry solids. This causes these sediments to settle upstream from the drainage structure, creating a gravel deposit or bar. Benthic invertebrates (bottom-dwellers) would be affected. The ponding could benefit fish populations. The water, with a high potential energy and no bedload, then passes through the drainage structure at high velocity due to the hydraulic head caused by ponding. This fast-flowing water rushes through the drainage structure and erodes and scours the downstream streambed. Perching of the drainage structure results (see figure 5 in appendix A). Such structures can also wash out during periods of high flow.

DEBRIS JAMS

Trees and branches can fall in streams during the right-of-way clearing, particularily in heavily forested areas. Debris, ranging from single logs to large jams, causes instability of the streambed, particularly if the debris shifts position with high flows (Helmers 1966). Relocation of gravel associated with shifting of debris has been known to result in high salmonid embryo and alevin mortalities (McNeil 1966). Another result of such gravel shifts may be the temporary reduction of bottom fauna (Narver 1970).

FRENCH DRAINS

If workpads, pipeline crossings, or access roads wash out, instream deposition of the washed-out gravels can form French drains (see figure 6 in appendix A). These deposits, which are formed when a stream channel is filled by gravels, rocks, or cobbles with no binder material, cause surface flows to dip below the ground surface before emerging above ground further downstream as surface flows. They may become evident only during periods of low flow. French drains can also form when poor grading processes at fords or pipeline crossings leave elevated or widened stream channels.

BANK DISRUPTION AND STABILIZATION

Sections of stream banks with their natural vegetation protection or armoring are excavated during the process of burying a pipeline across a river. Access roads and drainage structures can also disrupt stream banks.

Channel morphology is a compromise between the natural tendency of all streams to meander (Leopold and Langbein 1966) and the resistance to meandering provided by the stream bank soil and vegetation. Vegetation has been shown to protect stream banks in three ways: (1) it inhibits erosion by reducing water speeds and tractive forces at the soil surface, (2) it acts as a buffer against impact from ice, logs and other transported materials and (3) it contributes to bank stability.

Following the installation, bank stabilization and restoration are of prime importance. Bank stabilization is a long-term concern. Bank or bed instabilities can increase the long-term levels of suspended sediment in the water and possibly lead to a channel change.

Many conventional bank stabilization methods are available, including riprap, gabion placement, dike spurs, sacked cement, gravel lining, and several forms of restoration and revegetation. However, man-made bank stabilization procedures such as riprapping have environmental tradeoffs. Artificial structures alter the natural stream hydraulics by affecting stream bank roughness or friction which is directly correlated to stream velocities. These man-made structures introduce additional instability into the hydraulic system and could produce long-term adverse impacts to the aquatic resources.

BLOCKED FISH PASSAGE

The blocking of fish movement can occur during construction of pipeline stream crossings because of temporary damming, diversion, or fluming of streams with structures that prevent fish passage. Also, high turbidities due to crossing construction can disrupt spawning migrations. More permanent blockages can occur at jams of trees and branches that fall in streams during right-of-way clearing (Narver 1970). Culverts are a likely spot for such jams to occur. French drains also would block fish passage, as could large ruts that may form at fords (Gustason 1977). Long-term blockages to fish passage would occur where excessive velocities are created by inadequate drainage structures or channelized streams. Perched culverts are a common occurrence that can block fish passage. Insufficient water depths would also block fish passage. This could occur at oversized drainage structures that cause water to spread out over a wider area.

Fish passage is often impaired by excessive velocities. The swimming ability (speed) of the fish is a function of its size and body shape; usually the larger the fish, the faster it can swim. Swimming ability also varies among species. Bell (1973), as shown in table 3, gives ranges of swimming speeds for various fish species. Swimming endurance also is important; at any given water velocity, a fish can be expected to swim for only a given period of time before falling back. Excessive velocities may not allow total passage of a given run of fish, which may consist of three or four age classes with a wide range in individual size. The smallest fish (the weakest swimmers) often can not get through a design barrier even when larger ones can. Watts (1974) concluded that generally water velocities of 3 to 4 body lengths per second is a safe design velocity to allow for passage of the fish being considered, regardless of the culvert's length.

Another consideration is that swimming performance may be reduced by environmental stresses such as high water temperature, pollutants, siltation, or low dissolved oxygen (Gebhards and Fisher 1972), all of which can occur because of underground pipeline construction and maintenance.

Unrestricted passage of fish in streams is essential to the maintenance of wild fish populations. Fish passage in streams is most critical during migration. Blockage of streams could prevent use of important spawning drainages and result in large population declines. In many cases, small tributary streams provide most of the spawning habitat for fish from mainstem rivers. These streams are also the most vulnerable to blockages. Besides preventing reproduction, fish blocked or delayed from migration may concentrate at a barrier and become subjected to abnormal predation and fishing pressure (Gebhards and Fisher 1972).

Fish kills have been documented when outwash gravels and low flows prevented the downstream fall migration of fish (Gustason 1977). Any barrier could induce fish kills if it were to block out-migration of fish to deeper water during freeze-up, or when summer low flows, drought, or irrigation withdrawals reduced or eliminated surface streamflow. Blocked fish passage during summer low flows also may kill fish by preventing them from escaping higher temperatures in shallow water during this period.

TABLE 3. Swimming speeds of average size adult fish.

Species	Cruising speed[a] ft/s	Sustained speed[b] ft/s	Darting speed[c] ft/s
Carp	0 to 1.2	1.2 to 4.0	4.0 to 8.4
Suckers	0 to 1.4	1.4 to 5.2	5.2 to 10.3
Lamprey	0 to 1.0	1.0 to 3.0	3.0 to 6.3
Whitefish	0 to 1.3	1.3 to 4.4	4.4 to 9.0
Grayling	0 to 2.5	2.5 to 7.0	7.0 to 14.2
Brown trout	0 to 2.2	2.2 to 6.2	6.2 to 12.7
Trout	0 to 2.0	2.0 to 6.4	6.4 to 13.5
Steelhead	0 to 4.6	4.6 to 13.7	13.7 to 26.5
Sockeye	0 to 3.2	3.2 to 10.2	10.2 to 20.6
Coho	0 to 3.4	3.4 to 10.6	10.6 to 21.5
Chinook	0 to 3.4	3.4 to 10.8	10.8 to 22.4
Shad	0 to 2.4	2.4 to 7.3	7.3 to 15.

SOURCE: Bell 1973.

CONVERSIONS: 1 ft/s = .3048 m/s

[a] Cruising speed is the speed at which a fish can swim for extended period of time (an hour or longer).

[b] Sustained speed is the speed which a fish can maintain for several minutes.

[c] Darting speed is the speed a fish can swim for several seconds.

DESTRUCTION OF COVER

Stream bank vegetation, midstream logs and rocks, and undercut banks provide essential hiding cover for fish. Right-of-way clearing and river-crossing construction would reduce this hiding cover.

Hiding cover is an essential constituent of living space for all stream fish. Brook, brown, and rainbow trout abundance has been positively correlated with stream cover (Lewis 1969, Hunt 1971). Addition of cover has been demonstrated to increase salmonid abundance (Hunt 1971, White 1975), while cover removal has had the opposite effect (White 1973). Smallmouth bass also require shelter (Hubbs and Bailey 1938, Cleary 1956, Haines and Butler 1969), as do many other fish species (Scott and Crossman 1973).

Optimum cover habitat is characterized by low light level, slow current, overhead surfaces close to the streambed, and lateral surfaces that can be pressed against. Vegetation hanging into the water, logjams, and undercuts provide shade and overhead concealment, and protruding roots and other stream bank irregularities produce pockets of slow current that permit fish to maintain a stationary position in the current with minimal energy expenditure. In addition, cover that provides visual concealment from competitors increases the number of fish that can co-exist in a given area of stream (Kalleberg 1958, Hartman 1963).

ALTERATION OF STREAM DISCHARGE

The removal of a large amount of vegetation from a watershed can substantially alter existing streamflow patterns (Rothacher 1970, Hibbert 1967). Alteration of existing streamflow may be greatest where the right-of-way clearance for the pipeline necessitates the removal of a large amount of vegetation in small, steep, mountainous watersheds that have a large number of small streams or springs.

The majority of documented studies of streamflow alteration from vegetation clearing has involved the disturbance of larger areas within watersheds than is common for pipeline construction. Streamflow alterations from this cause would be long-term in forested areas. One-time flow alterations would occur during the withdrawal and discharge of water for the hydrostatic test and the abandonment water flush of the pipeline.

Alteration of existing streamflow, whether as an increase in peak flows or a decrease in minimum flows, has been known to affect resident fish populations (Carufel et al. 1973, Hynes 1970), particularly if the alteration of flow takes place during critical times, such as spawning, egg hatching, and fry rearing.

Sometimes a stream may be totally dewatered of surface flow during construction of water crossings. This would cause mortality of benthic invertebrates and eggs in the dewatered section. Invertebrates would quickly recolonize the area when uninterrupted flow resumed (Hynes 1970).

WATER QUALITY

Oil spills and sedimentation are not the only sources of impairments to water quality during pipeline construction and operation. Even though a series of cleaning pigs would be sent through the pipeline prior to hydrotest fillings, there would still be dirt and rust left inside the pipeline. Such materials contaminate the discharge water, increasing the concentration of suspended solids.

Analyses of water samples collected by Joint Fish and Wildlife Assistance Team (JFWAT) during dewatering of Pump Station 9 on the Tanana River hydrotest revealed that in mid-discharge the water contained 233 mg/l suspended solids. These concentrations increased to 24,820 mg/l suspended solids toward the end of the discharge (Hughes 1976).

When hydrotests are run in the winter, methanol or antifreeze is sometimes added to the water. This would harm water quality if discharged into waterways.

Addition of a bactericide or soda ash to hydrotest water to limit rusting of the inside of the pipeline, would affect water quality and may create additional adverse impacts if the water is discharged directly back into the environment.

If a hydrotest section is filled in one watershed and emptied in another, there could be transport of organisms between the watersheds. Biological transport probably would be limited to small organisms like bacteria. Detrimental organisms and diseases thus might be introduced into drainages where previously they did not exist.

As with any construction activity, treatment and disposal of human wastes is important from a health and biological viewpoint. Inadequate planning of treatment or disposal facilities may lead to contamination by human wastes. Such contamination could be significant if construction camps were not properly planned or if wayside camping with motor-homes or trailers provided the main housing for large numbers of construction workers.

The risk for introduction of sanitary wastes and toxic material will occur where construction storage and service areas are near streams or other bodies of water. The accidental discharge of fuels, waste oils, and other toxic materials into streams can cause fish kills and damage water quality.

ORGANIC DEBRIS

Some of the effects of organic debris falling in streams during right-of-way clearing have already been discussed in the sections on blocked fish passage and streambed alterations. This section discusses further problems associated with organic debris.

Like sediments, accumulations of small material such as bark, wood fiber, and leaves can fill the interstices in the substrate material resulting in a decrease in living space for stream invertebrates (Hynes 1960) and in refuges for young salmonids (McCrimmon 1954).

Water quality can also be impaired by organic debris in streams. As organic material decays, oxygen is used up by the respiration of bacteria, fungi, and protozoa. This can cause a change in the dissolved oxygen content of the water, resulting in a marked decrease in dissolved oxygen both in the intragravel and in the surface waters. This could affect fish survival, particularly with developing embryos in the gravel and with juvenile and adult stages in small shallow streams during low summer flows when fish are restricted to pool areas and riffles are not turbulent enough to replenish oxygen in the water through mixing with the atmosphere.

Organic debris can harm water quality in other ways than oxygen depletion. Leachate from logs (such as tannins and lignins) can be slightly toxic to young salmon and trout under experimental conditions (Schaumberg and Atkinson 1970). In the field a toxic situation would probably only occur where large quantities of debris accumulated in very small sluggish streams. In such a stream, hydrogen sulfide gas from anaerobic bacterial decomposition in the stream bottom would be released when the bottom is disturbed and would probably present more toxicity problems than leachates.

THERMAL EFFECTS

The body temperature of fish and aquatic invertebrates is almost the same as their external environment. Therefore, water temperature is an extremely important factor in the bodily functions and activities of these aquatic organisms.

The risk for thermal impacts may occur where pipeline right-of-way clearance necessitates the excessive removal of vegetation cover from beside streams thereby increasing the solar radiation reaching the water. Several studies have shown that excessive removal of vegetation cover from beside small streams may increase the maximum water temperature in the streams (Fredriksen 1965, Brown and Krygier 1967). If the hydrotest is run in winter, the water may be heated to prevent freezing. This water, when discharged, could raise stream temperatures. Increased water temperatures also result where water is ponded by undersized drainage structures and debris jams.

Increased maximum temperatures may cause mortality, particularly of fish in juvenile and embryonic stages; however, the major effect of elevated water temperatures is that it reduces growth, vigor, and resistance to disease (Fredriksen 1965). When temperature increases are not excessive fish growth can be enhanced. Temperature tolerances vary greatly between species. The physiological state and behavior of an animal are interdependent; therefore, temperature can influence fish spawning migrations, downstream migration of juvenile fish, microhabitat preference of fish and invertebrates, and many other behavioral functions of these animals.

INCREASED PRIMARY PRODUCTIVITY

Several factors could contribute to increased growth of aquatic plants (particularly algae) on watersheds where streamside vegetation is cleared for pipeline construction.

Photosynthesis could increase in the stream due to increased solar radiation reaching the stream. Algae growth could also be stimulated by increased water temperatures and nutrients released from decomposing debris. The end result of this could be increased growth of invertebrates and fish. However, there would be an increased oxygen demand from nocturnal respiration and decay of dead algae (Hynes 1960). This could decrease dissolved oxygen in the stream and harm aquatic animals.

ACOUSTIC SHOCK FROM BLASTING

If river crossings are constructed during the winter, frozen banks may have to be blasted before they can be excavated. Blasting also would be required if bedrock were encountered during trench excavation.

The acoustic shock effects of blasting result in another short-term impact on fish. This phenomenon has been studied primarily on ocean floors where blasting is used in exploration for off-shore minerals. Indications are that explosive pressures above 35,000 kg/m^2 (50 lbs/in^2) kill fish when explosives such as dynamite are used. Black powder creates a slower pressure wave and does not produce fish kills even at much higher explosive pressures (Hubbs and Rechnitzer 1952). Studies in freshwater stream environments are very limited, with recent research in Alaska being the most significant (Baxter 1970).

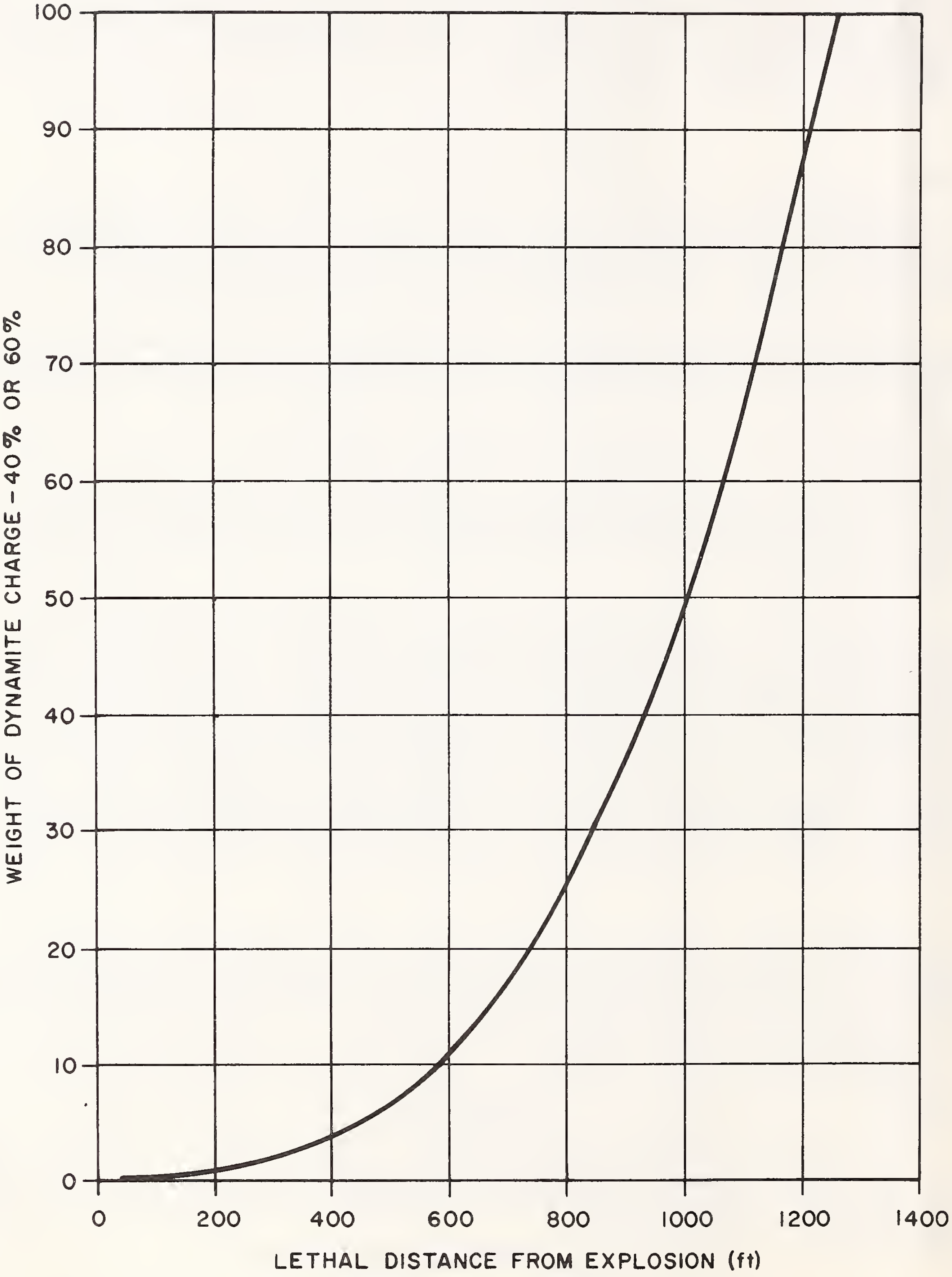
Baxter (1970) studied the effects of dynamite explosions on northern pike and confirmed that adverse effects occur on these fish when pressures of 28,000-35,000 kg/m^2 (40-50 lbs/in^2) are produced. This study indicates that all fish within 15 m (50 ft) of the site would be killed or severely injured by the explosion of two sticks of dynamite. The U.S. Corps of Engineers handbook of engineering requirements (Bell 1973) shows a relationship between charge weight of dynamite and the lethal distance to fish. Charges of several pounds or more can kill fish 60 to 122 m (200 to 400 ft) away, with 22-kg (50-lb) charges killing fish up to 305 m (1000 ft) away (figure 3).

Besides those from instream blasting, shock waves traveling through land to water can be lethal or damaging to fish. Disturbance of spawning behavior by blasting has also been observed (Fisher 1975). The disruption of the substrate by blasting can be detrimental to fish populations if important spawning gravels are destroyed.

ENTRAINMENT

During construction and hydrostatic testing many pumps may draw water out of streams. Fish and other aquatic organisms sucked through the intake of such pumps will be killed.

FIGURE 3. Swimming speeds of adult fish.



SOURCE: Bell 1973.

INCREASED FISHING PRESSURE

Workers in remote areas, with few if any recreational facilities, may "fish out" streams. This would be particularly true in small streams near construction camps. When small native populations are involved, such as in the west with some rare trout species (Behnke and Zarn 1976), this could be a serious problem.

ALTERATION OF ENERGY FLOW BETWEEN TERRESTRIAL AND AQUATIC SYSTEMS

The productivity of most small headwater streams in densely forested regions is supported mainly by photosynthesis which occurs in the adjacent forest (Fisher and Likens 1973). That is, most of the organic material in these streams comes from the breakdown of leaves and pine needles that fall in the streams. Because trees and brush adjacent to streams are cut down during right-of-way clearing, the amount of this material falling in the streams is altered and aquatic life affected, possibly in the form of decreased fish and invertebrate productivity. Large amounts of streamside vegetation probably would have to be cleared for this effect to be noticed. Therefore, this is a potential impact only where the pipeline right-of-way follows a stream along a narrow valley. Many other adverse impacts are already expected in such cases.

A related problem may occur because terrestrial invertebrates are a major food source for stream-dwelling salmonids (Hunt 1975). Different terrestrial vegetation types support different populations of insects. Also, many aquatic insects use streamside vegetation during emergence and in the adult stages of their life cycle. Therefore, altering streamside vegetation will alter the food supply for stream fishes. Conceivably, the replacement of brush and trees with grass as streamside vegetation could increase the supply of terrestrial insects (for instance, grasshoppers) available to fish. This is an area that needs further study.

CHAPTER FOUR

COMPARISON OF RELATIVE IMPACTS OF RIVER CROSSING TECHNIQUES

Many factors would enter into a decision as to which river crossing technique should be used at a particular crossing. These would include engineering feasibility, operations reliability, capacity for detection and repair of a spill below flow line measurements, leak containment, effects of construction on streambed and sediment yield, and visual concerns. The following discussion will consider these factors; in most cases there will be still more concerns. Cost, in particular, will enter into decisions. Another factor would be the predicted effectiveness of mitigating measures. Both cost and mitigating measures depend to a large extent on the site specific nature of the crossing.

ENGINEERING FEASIBILITY

There are no engineering barriers to either the aerial crossing or trenched methods. Currently, the directional drilling crossing method has low engineering practicality in mountainous regions with boulder-cobble substrates (NTPC 1979). Horizontally drilled crossings may also be limited by substrate.

OPERATION RELIABILITY

If a trenched or drilled crossing is buried beneath the maximum scour depth of the river, there is very little probability of its failing. Aerial crossings would appear to be more subject to sabotage or mechanical accident than buried crossings. However, information presented to the Montana Department of Natural Resources and Conservation on the reliability of pipeline suspension bridges indicated that no failures had occurred on over fifty such bridges in twenty-five years of operations even though planes have hit some bridges (Sandmeyer 1979).

LEAK DETECTION AND REPAIR

A major or minor pipeline failure in any aerial structure can be readily detected and located. This is not always the case with buried river crossings. A pipeline failure in any aerial crossing is also a great deal easier to repair than a similar leak in a buried crossing. A trenched river crossing would have to be reexcavated for repair, or abandoned, and a second trenched crossing installed. This would have to be done even if the pipeline failure was a minor leak such as those caused by corrosion. Failure of a drilled crossing would not involve instream disturbance for repair. If both the pipeline and the casing failed simultaneously or if the casing were crushed, the crossing probably would be abandoned. A new crossing could be installed by drilling with no instream disturbance. If the pipeline alone failed, and not the casing, the damaged pipe could be pulled from the casing and a completely new river crossing pipe pulled through it.

LEAK CONTAINMENT

The casement pipe used with drilled crossings decreases the probability of oil contaminating waterways in the event of a pipeline leak at a river crossing. If the pipeline failed and the casing did not, the crude oil would flow from the pipeline into the casing and then out the casing ends. If there were impervious catchments on the river bank, oil would not reach the water. Oil would enter the river only if both the oil and casement pipes failed.

In the past, trenched crossings have not been constructed with casement pipes. A leak, therefore, will contaminate the water if crossings are constructed in the conventional manner. It would, however, be possible to use a casement pipe on trenched crossings also. This would involve more instream excavating and involve more weighting of the pipe (due to its buoyancy) creating engineering problems and probably increasing construction impacts.

It would also be possible to put aerial crossings in a casement pipe and put catchment basins on the bank, minimizing the probability of oil reaching the river. Casement pipes on aerial crossings would have the added advantage of protecting the oil pipeline from such hazards as rifle fire.

It should be pointed out that catchment basins may not always be feasible because of landscape restraints. In addition, catchment basins could create visual impacts and require maintenance such as the pumping out of stagnant water.

EFFECTS OF CONSTRUCTION ON STREAMBED AND SEDIMENT YIELD

This is the primary subject of a review provided by a contractor for the pipeline engineering firm (NTPC 1979). This system rates impacts of the crossings without considering oil spill possibilities. Their potential for impact ranks trenched crossings as the least favored, overhead crossings as second most favored, and directional drilling as most favored. This appears reasonable in that directional drilling requires no alteration of streambeds or banks while overhead crossing requires bank alteration and possibly structural protection around the tower bases. Trenched crossings require both bank and bed excavation. Horizontally drilled crossings were not ranked by Butler but probably would create less sediment problems than aerial crossings because the streambanks are not disturbed, but the silt laden water pumped from pits and tunnels has the potential to create greater sediment impacts than that from directionally drilled crossings.

VISUAL CONCERNS

The 91-m (300-ft) towers associated with aerial suspension crossings would cause major visual impacts except where they are located near other towers associated with other pipelines or power lines. A further visual impact would be created when riprap is used for stabilizing cut down banks. The subsurface methods would have similar visual impacts, except when trenched crossings require extensive riprapping for bank stabilization. Visual impacts have no significance to biological resources, but undoubtedly would be used in making a final selection of crossing types.

CONCLUSION

This report makes no recommendation as to the choice of stream crossings; such a recommendation requires a great deal of site specific information, culminating in a professional judgment. For example, the choice of methods could depend upon a decision as to whether the possibility of higher frequency of oil spills from an overhead line outweighs the certainty of increased sediment and erosion associated with buried crossings. Engineering feasibility is the primary consideration in the directionally drilled method.

CHAPTER FIVE

MITIGATING MEASURES

This chapter describes a range of measures that could be taken to reduce the severity of impacts on aquatic life and habitats from construction, operation and maintenance, and abandonment of a pipeline system. The measures pertain only to aquatic resources; consequently, some may conflict with measures pertaining to other concerns, such as soils and vegetation, wildlife, land use, visual impacts, or pipeline engineering and economics.

To identify the measures that would provide the most effective mitigation of a project's overall impacts (not just its impacts on aquatic life and habitats), it would be necessary to examine all the possible mitigating measures for all concerns and assess the trade-offs among concerns. Several other factors would influence selection of mitigating measures: the laws, regulations, and policies governing pipeline siting, construction, operation, and maintenance; the statutory authority to ensure implementation of measures; and the cost-effectiveness of mitigation in specific situations. Thus, the mitigating measures for aquatic resources that would be implemented for a particular project would probably not be identical to all those identified in this chapter.

LOCATION OF A PIPELINE AND ASSOCIATED FACILITIES

The potential for damage to aquatic life and habitats would be reduced by:

1) Locating the pipeline route and related facilities, such as access roads and pump stations, in areas where the cumulative risk of damage to aquatic life and habitats would be least. (This would involve a comparison of biological and hydrological characteristics of the drainages that would be affected by alternative routes. Possible criteria for route comparison are given in appendix B.)

2) Having an aquatic biologist and hydrologist inspect a proposed centerline and, wherever practical, modifying a proposed centerline and the location of associated facilities to avoid sites where there would be a high risk of damaging aquatic life and habitats. General guidelines for centerline placement would include:

    a) Avoiding stream crossings and encroachment onto streambanks, and in general, leaving buffer strips of undisturbed land at least 150 m (500 ft) wide along water bodies.

    b) Crossing streams and rivers at right angles to keep crossings as short as possible.

    - c) Crossing streams where the least abundant microhabitat (e.g. fish's cover, spawning, or feeding) will be disrupted.
    - d) During egg and larval periods, constructing stream crossings downstream from gravel beds, or when that is impossible, constructing the crossing as far upstream from the gravel bed as possible.

CONSTRUCTION RELATED OIL SPILLS

Taking the following measures before construction would reduce damage caused by oil spills related to construction:

1) Formulating a plan to take care of oil spills and having that plan reviewed and agreed upon by all participating parties. A good plan would include at a minimum: (a) procedures for reporting spills; (b) definitions of what constitutes a spill; (c) methods of containing, recovering, and cleaning up spilled oil; (d) a list of needed equipment and its location; (e) a list of all agencies and management personnel that would have to be contacted in the event of an oil spill; and (f) assurance that the chemicals and procedures used to clean up oil spills are themselves not detrimental to the aquatic community.

2) Briefing all personnel thoroughly on reporting procedures in the event of a major or minor spill.

3) Decreasing the likelihood of oil spills by:
    - a) Using care during refueling to guard against overflows.
    - b) Storing fuel in metal petroleum tanks instead of fuel bladders.
    - c) Surrounding oil storage facilities with impervious dikes.
    - d) Hauling away waste oil and not allowing it to run out onto the right-of-way.
    - e) Educating workers and management to give them an awareness that their actions have environmental consequences.
    - f) Inspecting equipment frequently for leaks and making appropriate repairs.

4) Refueling and repairing equipment where any spilled petroleum will not enter a waterway.

5) Having sufficent equipment to clean up at least a 18,900 l (5,000 gal) spill readily available.

6) Inspecting oil spill clean-up equipment frequently to ensure that it is in good working order.

MAINLINE OIL SPILLS

The likelihood of and the damage caused by a mainline oil spill could be reduced by the following:

1) Developing a mainline oil spill contingency plan describing how the pipeline company would deal with the large amount of oil that could be spilled from a mainline accident before actual operation of the pipeline. (The contingency plan should in general follow the previous description for control of construction-related oil spills).

2) Designing and installing sensitive oil leak detection units at all stream crossings to minimize the possibility of undetected leaks.

3) Locating block or check valves on both sides of streams and all other bodies of water considered by responsible state or federal resource agency representatives to be of significant value.

4) When feasible, using pipe-within-a-pipe construction at stream crossings so that spilled oil is led to catchment basins on the bank to decrease the probability of oil entering the stream.

5) Placing pipe at least 1.2 m (4.0 ft) below the maximum predicted depth of scour as established by field investigations and calculations that are agreed upon by both the company and those government agencies concerned.

6) Designing the pipeline to be able to withstand the effects of weather, hydrology, and hydraulics of each region through which the pipeline passes. (These effects would include runoff, stream and floodplain erosion, meander cutoffs, lateral migration, ice jams, and icings.)

7) Requiring detailed plans for corrosion-resistant designs and methods for early detection of corrosion. These would include:

    a) Pipe material and welding techniques to be used, and information on their particular suitability for the environment involved.

    b) Details on the external pipe protection to be provided (coating or wrapping, etc.), and information on variation of the coating process to cope with differing environmental factors along the pipeline route.

    c) Plans for cathodic protection, including details of impressed current sources and controls to ensure continuous maintenance of the pipe.

    d) Details of plans for monitoring cathodic protection current, including spacing of current monitors.

    e) Provision for periodic intensive checks of trouble spots, regular preventive maintenance surveys, and special provisions for abnormalities in electric potential patterns resulting from the crossing of the pipeline by other pipelines or cable.

    f) Information on precautions to be taken to prevent internal corrosion of the pipeline.

8) Requiring impervious oil spill containment dikes or equivalent structures around storage tanks at pumping stations and at other facilities related to the pipeline that have a volume of at least: (a) 110 percent of the total storage volume of the storage tanks in the area; and (b) a volume sufficient for maximum trapped precipitation and runoff which might be impounded at the time of the spill.

9) Constructing oil spill containment dikes to withstand failure from earthquakes and riprapping them on the outside in flood plains for protection from flood waters.

10) Locating pump stations as far away from waterways as possible.

STREAM AND RIVER CROSSINGS

The many possible impacts to aquatic life and habitats associated with stream and river crossing could be reduced by using the following measures:

1) Constructing stream crossings in compliance with applicable water quality standards as approved by the Environmental Protection Agency (EPA), with requirements of the waste discharge permit program of the EPA National Pollutant Discharge Elimination System, and all applicable discharge permit programs. In Montana, the Department of Health and Environmental Sciences administers such programs and standards.

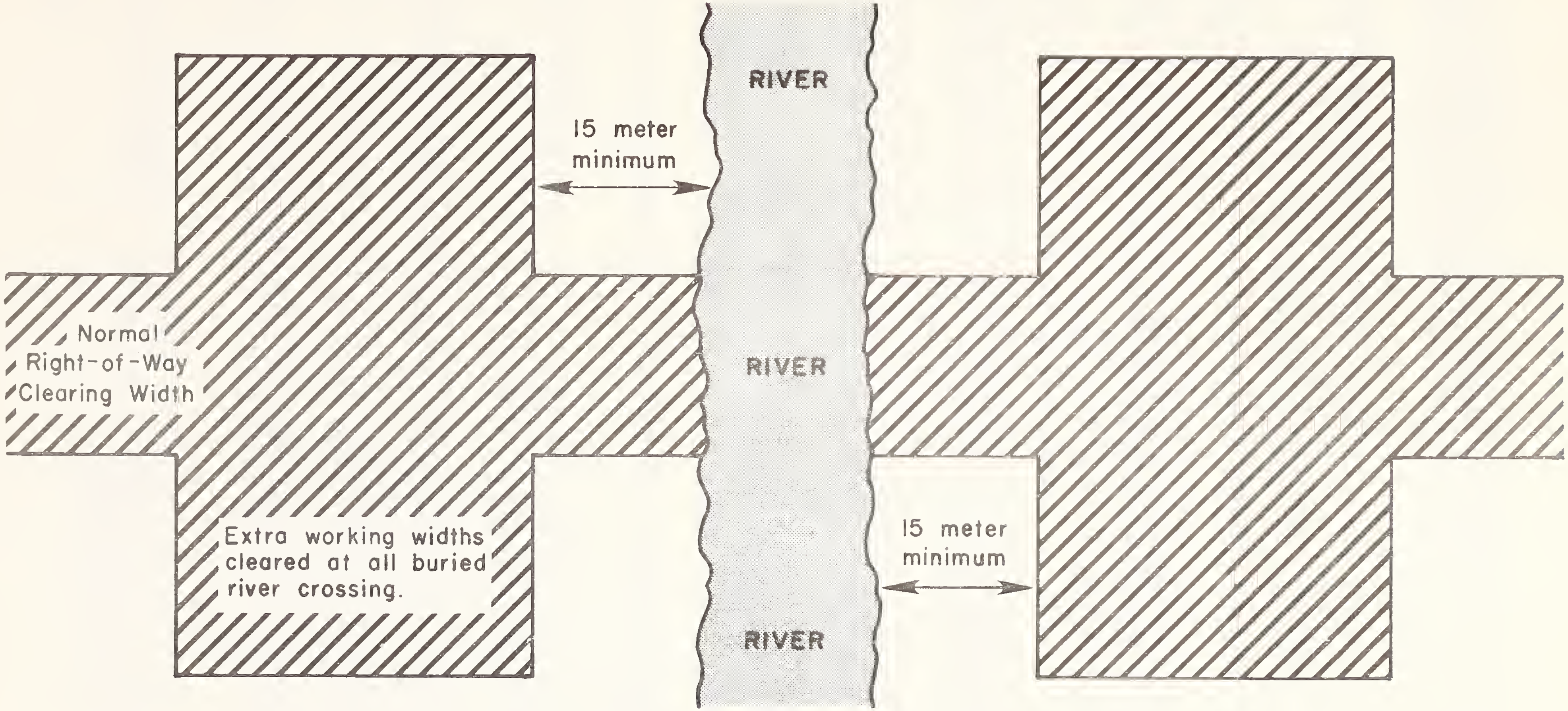
2) Having the site of the stream crossing inspected and the construction plans approved before beginning construction of a stream crossing.

3) Constructing buried stream crossings during periods least critical to fisheries, and when sediment transport would be the least. (Critical time periods for fisheries vary from stream to stream, depending on fish species present. Sediment transport is least during periods of low flow.)

4) Drilling under, or constructing aerial crossings over, biologically unique or very sensitive streams.

5) Preventing any displaced materials or petroleum products from entering the stream during test boring to determine understream material.

FIGURE 4. Recommended method of minimizing impacts of additional right-of-way clearing at buried river crossings.


RIVER
RIVER
RIVER
15 meter minimum
15 meter minimum
Normal Right-of-Way Clearing Width
Extra working widths cleared at all buried river crossing.

6) Ensuring that support structures for aerial crossings are located away from or adequately protected from the effects of scour, channel migration, undercutting, ice forces and other external and internal loads.

7) Pumping the silty water to a settling pond before returning it to the river when it is necessary to dewater excavated footing sites for suspension towers, pits, or the pipeline trench.

8) Covering pump intakes with screen boxes to prevent harm to fish.

9) Clearing extra working widths at river crossings for the temporary storage of excavated ditch spoil in a manner that leaves a 15-m (50-ft) buffer strip of natural vegetation between the storage sites and the river (figure 4).

10) Constructing all trenched river crossings in the shortest time possible, working 24 hours a day from the time the crossing is started until it is complete to reduce the time during which silt can be washed into the river.

11) Using hard plugs, soft plugs, or silt curtains and other construction methods to reduce the amount of silt entering the stream and the distance it is transported.

12) Fluming or pumping the flow of smaller streams around the crossing site during construction.

13) Allowing no temporary instream storage of ditch spoil.

14) Removing excess ditch spoil to areas where it cannot reenter the stream.

15) Pumping ditch spoil excavated with a suction dredge through a temporary floating pipeline to an impervious, diked site where the spoil will not reenter the stream.

16) Backfilling the crossing with granular material containing little silt, if the excavated ditch material is not suitable for backfill.

17) Using backfilling materials that cause no significant aggregation or degradation instream.

18) Restoring stream channels and banks approximately to their original configurations and replanting the banks with trees and shrubs to make them stable.

19) Using riprap or gabions to stabilize the banks only as a supplement to natural vegetation or to stabilize the banks until the vegetation is established.

20) Burying the pipeline deep enough at crossings so that tree roots would not be a hazard to it.

21) Using tree stumps removed from the right-of-way to stabilize the streambank and provide fish cover.

22) Using fill ramps for temporary access over streambanks rather than cutting ramps through streambanks and removing the ramp and reestablishing the thread of the stream when the crossing is completed.

23) Preventing solid matter, debris, and contaminants from spilling into waterways, lakes, and underground waterways.

24) Using equipment in waterways as little as possible and steam cleaning it before it enters the water.

25) Reducing peak pressures of instream and streambank blasting by using the smallest amount of explosives needed and, when more than one charge is used, wiring them in series with at least a 17-millisecond detonation delay between each. (On TAPS, a powder factor of one pound or less per cubic yard was used when the pipeline company had to blast near any fish stream.)

26) At crossing sites where a river's flow is naturally divided into two stable channels, diverting the entire flow through one channel while constructing the crossing across the other.

CLEARING THE CONSTRUCTION RIGHT-OF-WAY

Damage from clearing a construction right-of-way would be reduced by following these measures:

1) Clearing a construction right-of-way that is the minimum width necessary to allow construction to proceed expeditiously.

2) Considering both environmental and engineering concerns when making decisions on right-of-way width. (While narrower rights-of-way could result in less damage to aquatic life and habitats, construction within a narrow right-of-way would be more difficult, costly, and time consuming than construction within a wide right-of-way. Also, a very narrow right-of-way would impede revegetation because it would not allow room for segregation of topsoil and subsoil.)

3) Hand-clearing the right-of-way within 30 to 45 m (100 to 150 ft) of all waterways.

4) Felling all trees, snags, and other wood material away from water ways.

5) Immediately removing any debris that may accidentally fall in waterways during right-of-way clearing. (Heavy equipment should not be allowed in stream for debris removal.)

6) Prohibiting use of pesticides and herbicides near streams.

USE OF THE RIGHT-OF-WAY

Adverse impacts on aquatic life and habitats from use of right-of-way would be reduced by taking the following measures:

1) Restricting or prohibiting construction activities involving motorized travel at times of the year when soil is saturated with moisture or when motorized travel would cause ruts and channels, or create wind erosion.

2) Spending the least amount of time in areas where motorized vehicles would have to cross saturated soils.

3) Prohibiting motorized travel on, scarification of, or displacement of talus slopes, except where absolutely necessary.

4) Carrying out construction and operating vehicles in a manner that would minimize dust pollution.

5) Using materials other than oil or similar petroleum derivatives to control dust.

6) Allowing only experienced personnel to operate earth-moving equipment.

7) Keeping the right-of-way bare of vegetation for the shortest possible time to limit the time erosion runoff would be likely to reach surface water.

8) Controlling erosion during construction and before revegetation with sediment traps, berms, slope drains, toeslope ditches, diversion channels, sodding, and mulching.

9) Building sediment retention basins where they can catch sediment from the right-of-way or access roads before it can endanger the quality of nearby waterways.

10) Preventing off-road vehicle use of the right-of-way.

ACCESS ROADS

Adverse impacts on aquatic life and habitats from pipeline access roads would be reduced by taking the following measures:

1) Building the fewest new access roads required to construct a pipeline system. (See footnote 2 on page 4 for a definition of access roads.)

2) Designing and constructing the new roads it would be necessary to build to serve as maintenance roads during pipeline operation.

3) Having the location of all new roads approved before construction begins.

4) Leaving a 150-m (500-ft) buffer strip of undisturbed land between roads and waterways whenever possible.

5) Clearly marking the location of access roads before equipment is moved to construction sites, and posting restrictions on use of roads.

6) Designing roads to accommodate the largest piece of equipment that would be used and constructing roads no wider than would be necessary.

7) Constructing new roads with the minimum possible clearing and soil disturbance, and in a manner that would minimize erosion.

8) Constructing temporary roads on flat land (where it is available and where construction would be practical) to avoid damage from blading and grading.

9) Adequately maintaining roads while they are in use to avoid damage (for example, promptly filling ruts made by machinery to prevent channelling of runoff).

10) Using water, straw, wood chips, dust palliative, gravel, and combinations of these materials, or similar materials to control erosion.

11) Prohibiting unauthorized cross-country travel and development of unauthorized roads during construction.

DRAINAGE STRUCTURES

Damage to the aquatic environment could be reduced by the following measures:

1) Using the drainage structure most suitable for each site's soil conditions and stream morphology.

2) Designing all drainage structures to pass the Q_5 at slow enough water velocities to allow passage of fish of the region, and permanent drainage structures to pass the Q_{50} flow, but also taking care to ensure that the structures are not too large, creating flows too shallow for fish passage.

3) Installing drainage structures that do not alter the natural hydrogeologic balance of streams.

4) Constructing drainage structures only one lane 4.5 to 6 m (15 to 20 ft) wide so that the stream is disturbed as little as possible.

5) Constructing all crossings at right angles to the streambed.

6) Designing and constructing the slopes of cuts through streambanks to reduce erosion as much as possible and prevent slides.

7) To cross all fish streams, using bridges that completely span the natural streambed (with no instream pilings) and that have approaches that do not restrict the normal floodplain. Bailey-type bridges can be easily disassembled, moved to new streams, used repeatedly at numerous crossings, and sold at the end of construction.

8) Removing temporary bridges without damaging streambanks or streambeds.

9) Using culverts on fish streams only where the gradient is 0.5 percent or less, where flows are near constant, where there is little or no bedload transport, and where there is a low susceptibility to icing or plugging with debris.

10) Placing energy dissipation structures at the outlets of culverts used on high gradient ephemeral drainages.

11) Armoring culvert inlets and outlets with appropriate material to prevent erosion.

12) Constructing, where necessary because of outlet erosion, settling basins at the lower end of culverts.

13) Placing the bottom of culverts .15 m (0.5 ft) below the natural streambed at the outlet.

14) Placing proper bedding, padding, and coverings around culverts to prevent them from being crushed by heavy equipment.

15) Using by-pass pumps to dry the streambed while culverts and fords are being installed.

16) Using temporary bridges or culverts but not fords during the construction phases of the project, although temporary culverts may be replaced with fords built to specifications after construction, provided only occasional traffic is anticipated during operation and maintenance.

17) Using fords only as drainage structures on ephemeral drainages or streams without fish.

18) Not installing fords at deeply incised streams or in unstable soils where banks would require excessive excavation.

19) Constructing fords to match the existing stream geometry as closely as possible.

20) Selectively choosing, sorting, and mixing the fill material used in the construction of fords to be in the proper proportions to support traffic, prevent rutting, reduce siltation, prevent washouts, preclude French drains, and allow fish to pass freely. (Deep layers of small angular and subangular rock, chinked with a sufficient amount of finer particles for a binder, provides one of the best surfacings to meet these criteria. Rounded river cobbles, silty pit run materials, regraded stream bottom material, thin layers of shot rock, and general workpad materials should never be used as filler in constructing fords.)

CONSTRUCTION CAMPS AND EMPLOYEE FACILITIES

Damage to the aquatic environment associated with human developments can be reduced by taking the following precautions:

1) Planning facilities adequate to accommodate the construction crews, their families, and other support people.

2) Constructing such construction camps so that they meet all of the water quality laws with regard to sewage treatment and water supplies.

3) Locating such camps away from any flood plain or surface water that could be contaminated by sewage, accidental fuel spills, or solid or other types of waste.

4) Requiring flow meters on fuel lines and tanks to detect leaks.

5) If small community facilities are to be used, having the sewage treatment and garbage disposal systems investigated by the appropriate agency to determine which are adequate to handle the increased loads.

6) Requiring special fishing restrictions and recreational use permits from the appropriate agency to accommodate the increased demand near construction camps.

MATERIAL SITES

Damage to aquatic systems can be reduced by taking the following measures:

1) Having the pipeline company prepare a detailed plan for material sites.

2) Following proper siting and development in accordance with the law, with restrictions on the development of any flood plain or similarly sensitive site.

3) If material sites are approved adjacent to or in lakes, rivers, streams or wetlands, constructing levees, berms or other suitable means to protect fish and fish passage, and to prevent siltation.

HYDROSTATIC TESTING OF THE PIPE

Damage to aquatic systems can be reduced by taking the following measures:

1) Withdrawing no more than one-eighth to one-fourth of the stream flow during hydrotesting.

2) Adequately addressing the question of water laws and water rights, including reserved instream flow, in plans to withdraw water for hydrotesting to ensure that they are consistent with all legal requirements.

3) Excavating only where the streambed or streambanks have already been disturbed (as in a trenched crossing) if a bank must be cut down or a sump enlarged for a pump.

4) Hauling excavation materials to a place where they will not wash into the waterway.

5) Placing each pump intake within a 0.91 m (3 ft) square, screen-box to prevent fish from being sucked into the pumps and pump suction from holding small fish against the screened side, as could happen with use of a smaller pump intake box.

6) Attaching an energy dissipation system to the end of each discharge line and staking plywood flat on the ground beneath the end of the energy dissipator so that the water will flow over the plywood before it reaches the ground.

7) Not discharging water onto steep slopes.

8) If the water must be emptied onto a steep slope, choosing the location so that the water is not funnelled into a natural drainage below the energy dissipation system.

9) Not emptying the test water (which has high levels of grease, oils and suspended sediments) directly into any waterway. Because of the water quality impacts and the erosion potential of the discharge water, it is preferable to empty the hydrotest water into a dead slough that contains no valuable aquatic resources and is not directly connected to a waterway. If there is absolutely no alternative, the first one-half to three-quarters of the hydrotest water could be discharged directly into a river, but the

concentration of oil, grease and suspended solids in the last portion of the discharge water makes it imperative that this portion never be discharged into any live stream without applying chemical or physical treatment to remove the contaminants.

10) Regulating the use of methanol or antifreeze in hydrotest water. (If it is necessary to hydrotest the pipeline in below freezing weather, heated water could be used. Heated water should be allowed to cool before it is discharged into streams).

MONITORING CONSTRUCTION

Damage to aquatic systems resulting from pipeline construction would be reduced if a biologist and hydrologist monitored construction to ensure consideration of aquatic life and habitats.

COMPENSATION

Damage to aquatic systems resulting from construction or operation of a pipeline could be partially mitigated by paying the value of fish lost. The value of fish could not be a fixed amount because it is increasing at a highly accelerated rate; thus, the value should be determined following damage.

APPENDIX A

PHOTOS OF CONSTRUCTION ON THE TRANS-ALASKA PIPELINE

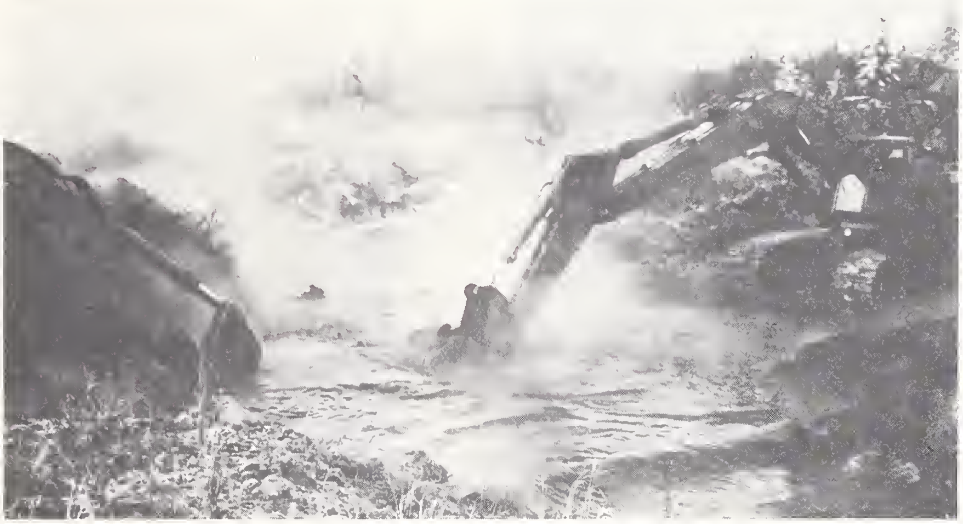


Figure A-1. Backhoes excavating a stream crossing.

(Photo by Charles Kay.)

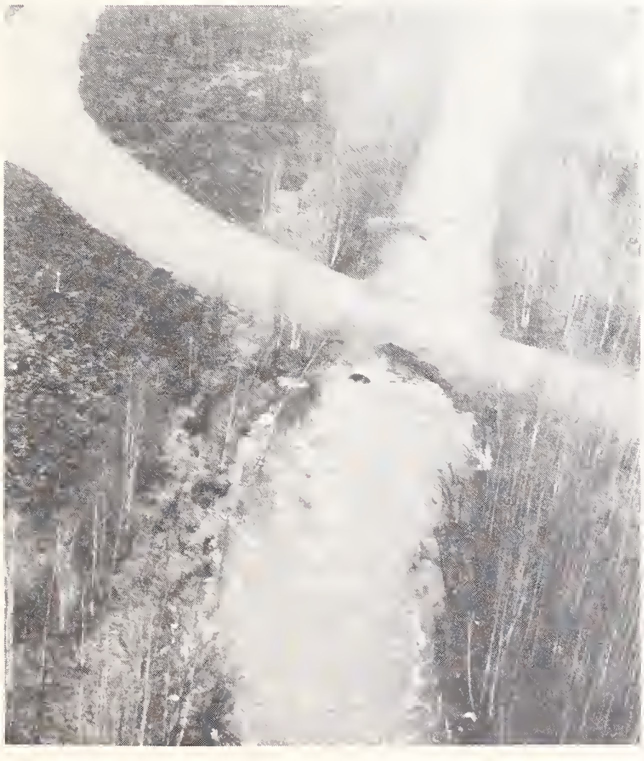


Figure A-2. Access road wash-out at a misaligned and undersized culvert.

(Photo by Charles Kay.)

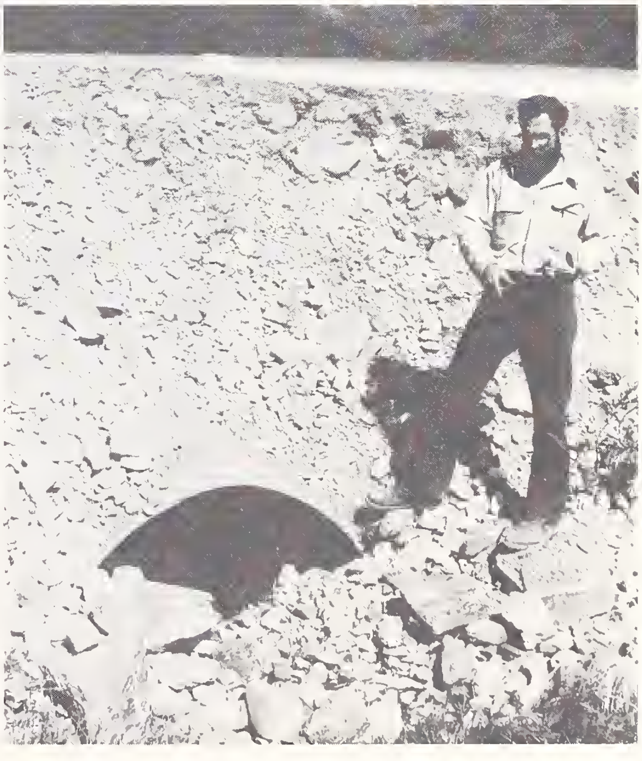


Figure A-3. Culvert blocked by gravel graded off the road.

(Photo by Charles Kay.)

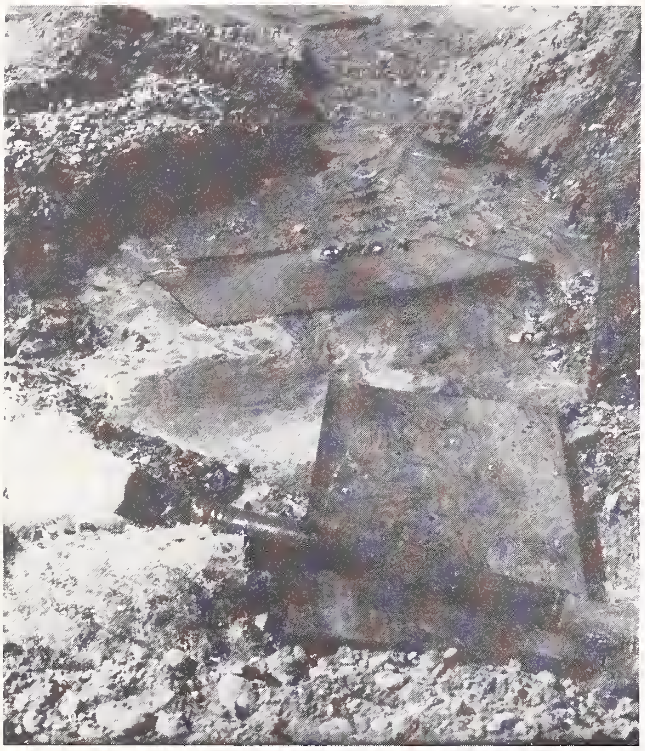


Figure A-4. Hydro test discharge water washing ditch spoils into a stream.

(Photo by Charles Kay.)

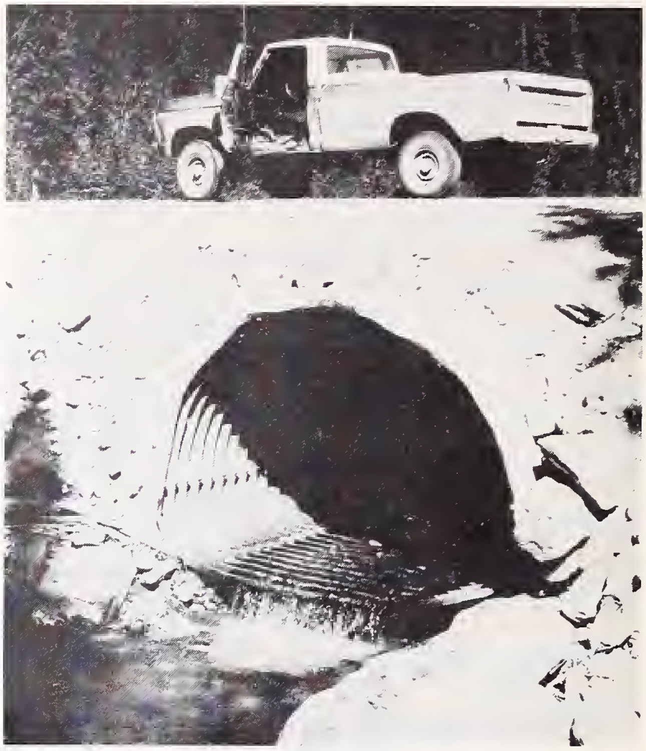


Figure A-5. Perched culvert.

(Photo by Charles Kay.)

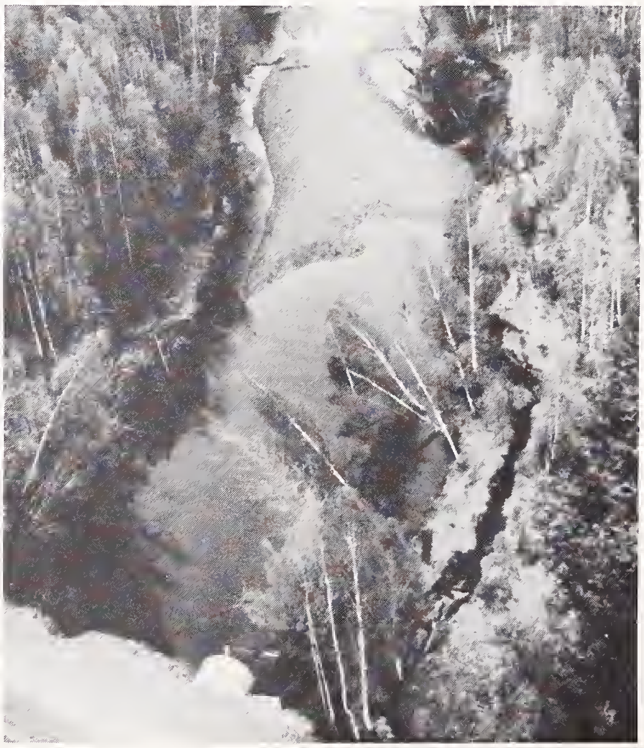


Figure A-6. Outwash gravels and bank material deposited below undersized culvert.

(Photo by Charles Kay.)

APPENDIX B

CRITERIA USED TO EVALUATE POTENTIAL DAMAGE ALONG ALTERNATIVE NTPS ROUTES

The following sections describe criteria used by DNRC to evaluate relative potential for damage to aquatic life and habitats along alternative routes of the NTPS. Similar information could be used in other regions for route comparisons. These criteria were selected on the basis of availability of data and the suitability of that data for general regional comparison. Such information is of limited use in evaluating the suitability of specific sites for river crossings but it provides a good depiction of impact risk and the overall quality of the aquatic habitat along a route. The tabulated information is in DNRC's draft EIS on the NTPS.

FISHERIES COMPARISON

The Montana Department of Fish, Wildlife, and Parks has devised a stream classification system which can be used as one of the criteria for evaluating potential impact of pipeline construction and operation on aquatic resources. In this system, stream reaches are assigned to one of six value classes. The value classes are as follows: (1) highest valued fishery resources, (2) high priority fishery resources, (3) substantial fishery resource, (4) limited fishery resource, (5) low value fishery, and (6) not classified. This system considers such things as the species of fish present, fish productivity, spawning, fisherman use, importance for nature study, and esthetics. These classes, then, reflect the relative value of the fisheries in the areas that could be affected by the pipeline. An explanation of methods used to arrive at value classes can be obtained from the Montana Department of Fish, Wildlife and Parks.

Classes of streams crossed or paralleled within 225 m (738 ft) and the highest class reach within 10 km (6.2 mi) downstream of a crossing or paralleled section were tabulated in the NTP draft EIS. Parallelism was considered because there is an increased chance of impact on the river from runoff or oil spills wherever the pipeline closely parallels a stream. Fisheries downstream from small or intermittent drainages crossed by the pipeline must be considered because a major oil spill in a small drainage could reach lower streams. Due to the site specific nature of how far oil will travel after a spill, the distances of 225 m (738 ft) and 10 km (6.2 mi) are somewhat arbitrary, but for the purpose of comparison they are probably adequate. Prior to centerline survey, all tabulations along routes would necessarily be tentative, but still adequate for route comparison.

WATER QUALITY COMPARISON

Water quality is an important consideration for livestock, irrigators, municipalities, and industry as well as aquatic life and habitats. Oil spills and increased turbidity reduce water quality. Therefore, the water quality ratings developed by the Montana Department of Health and Environmental Sciences for crossed streams were tabulated for route comparison. These ratings indicate the water quality necessary to support specific uses; the highest ratings and the most demanding criteria are reserved for municipal water supplies. The lower ratings indicate that the water is suitable only for industrial or agricultural uses. A description of the rating system is available through the Montana Department of Health and Environmental Sciences.

FLOW VOLUMES

The flow volume of a stream is an important consideration in evaluating the potential impact on the stream. Larger streams provide water for more use over a wider area and are generally more difficult to cross. Flow volumes were recorded for streams crossed and for streams within 10 km (6.2 mi) downstream of crossings. The flow volumes were taken from the U.S. Geological Survey Water Data reports. Ungauged stream reaches were placed in categories with similar streams for which data were available.

STREAM GRADIENTS

Gradients were obtained from U.S. Geological Survey quadrangle maps and tabulated for streams crossed by the pipeline along the various routes. Gradients are important because oil spills in fast flowing streams would be more difficult to contain. Swift streams would release more sediment during crossing construction, but would flush out the sediments sooner.

MULTIPLE CROSSINGS

Multiple crossings of the same stream were recorded. Crossing the same stream more than once would concentrate rather than dilute the impact on that stream and increase the risk of an oil spill entering that stream.

LAKES AND RESERVOIRS

Lakes and reservoirs which are often major recreation areas could be adversely affected by oil spills at stream crossings upstream. These water bodies, however, could contain oil spilled upstream. Lakes and reservoirs within 10 km (6.2 mi) downstream of stream crossings were recorded.

PUMP STATIONS

Chances for oil spills are greater at pump stations than at other locations along the pipeline. Therefore, pump stations were considered wherever they were close to a waterway.

SUMMARY OF CRITERIA

In summary, the criteria used for examination of probable impacts on aquatic resources by the alternative pipeline routes are based on general regional information. Determination of the best centerline location for stream crossings and other environmentally sensitive areas, such as flood plains or wetlands, requires field surveying by a qualified biologist.

GLOSSARY

alluvium--Unconsolidated geologic materials deposited by the running water in which they were transported.

aquifer--A formation, bed, or zone containing water that is available to wells.

berm--An embankment of fill.

boom (oil)--A floating device to contain oil spills within its boundaries.

buried crossing--A crossing of road, railroad, stream or other obstacle by laying the pipe underground below the obstacle.

cofferdams--Fill (usually sandbags) placed to prevent flow of water under and around a flume pipe or through an instream construction area.

diatom--Microscopic algae, whose walls consist of two valves.

diatomeceous earth--Earth principally composed of siliceous skeletons of diatoms.

discharge--Outflow; flow of water from a pipe, canal or river.

easement--A legal agreement in which a landowner grants the pipeline company the authority to carry on certain pipeline-related activities within a specified area.

> construction easement--A legal agreement in which the landowners grant the pipeline company authority to carry out all activities necessary to install the pipeline. Usually granted for a wider parcel of land than the construction right-of-way.
>
> permanent easement--A legal agreement in which the landowner grants the pipeline company authority to carry out pipeline operation and maintenance activities on the land in proximity to the pipeline. Usually granted for a wider parcel of land than the permanent right-of-way.

feet head--The measure of the pressure against which a pump forces a liquid.

fish windows--Period of time during which instream construction is allowed because of little risk of damage to fish populations during those periods. (opp. sensitive period) flange--A circular pipe coupling made in two halves. Each half is welded to a length of pipe and the two halves are bolted together.

floodplain--A strip of relatively smooth land, bordering a stream, that is subject to flooding; thus certain construction activities are regulated or prohibited on it.

flume--(1) An artificial channel. (2) To divert fluids through a flume, as the waters of a stream, in order to expose the sand and gravel forming the bed.

gabion--A metal cage filled with heavy material used in stabilizing streambanks.

lateral migration--Removal through erosion of bank material, soil, and rock adjacent to stream channels.

mandril--Support that is placed inside a pipe to prevent flattening during pipe bending.

meander--Wide curve in rivers and streams.

meander cutoff (meander belt)--The area channelized between lines drawn tangential to the extreme limits of fully developed meanders.

periphyton--Aquatic organisms that attach themselves to underwater surfaces.

plankton--Suspended microscopic plant and animal life found in bodies of water.

pressure head--The height to which liquid must be raised.

primary producers--Photosynthetic or chemosynthetic plants at the base of the first trophic level of food chains.

primary production--The production of glucose and related organic compounds by chlorophyll-bearing plants called primary producers.

Q--The hydrologic abbreviation for discharge.

riffle--(1) Rocky obstruction in a stream causing a ripple. (2) That stretch of shallow rapid water, caused by an obstruction in a stream.

right-of-way--The strip of land appropriated by a pipeline company through easement, condemnation, or fee ownership.

construction right-of-way--The strip of land, appropriated by a pipeline company, that is actually disturbed during construction of a pipeline; usually larger than the permanent right-of-way.

permanent right-of-way--The strip of land, appropriated by a pipeline company to accommodate maintenance activities during operation of the pipeline; usually narrower than the construction right-of-way.

riparian--Pertaining to the bank or shore of a river, lake or stream.

route--The general location of a pipeline right-of-way, subject to adjustments of 1.6 km (1 mi) or more during centerline location.

sackrete--A sand and cement mixture in bags piled along the streambank to stabilize.

salmonid--A fish of the salmon family (Salmonidae), such as salmon, trout, char, and whitefish.

sediment--Fragmented material that originates from weathering and erosion of rocks and is transported by, suspended in, or deposited by water or air or is accumulated in beds by other natural agencies.

sedimentation--The deposition of sediments.

sensitive areas--Those areas where (1) a resource of county-wide, statewide, or national importance is likely to be significantly and adversely affected if not adequately mitigated, (2) where terrain or other constraints would require costly or unconventional construction techniques or greatly increased construction time and costs, or (3) where risk of damage to the pipeline is high.

soft plug--A trench at a stream's edge that does not yet contain pipeline but has been filled with dirt to prevent silty water in a floodplain from contaminating the stream, or to provide temporary access across the trench.

stream channel-(watercourse)--A natural or artificial open conduit which periodically or continuously contains moving water or which forms a connecting link between two bodies of water. Rivers, creeks, runs, branches, and tributaries are natural channels.

stream reach--Any length of river.

substrate--The physical surface upon which an organism lives.

viscosity--The resistance of a fluid to flow.

LITERATURE CITED

Alaska Department of Environmental Conservation. 1977. Summary of Alyeska spill report data. 200 p. State of Alaska Department of Environmental Conservation.

Alford and Peters. 1963. Man-made channel alterations in thirteen Montana streams and rivers. Montana Fish and Game Department Project Reports.

Bailey, Jack. 1957. Game fish loss associated with highway construction. Montana Fish and Game State Project Reports.

Baxter. 1970. Blasting fish effects information file of C. Burger. U.S. Fish and Wildlife Service, Anchorage, Alaska.

Behnke, R. J. and Zarn, Mark. 1976. Biology and management of threatened and endangered western trouts. USDA Forest Service General Technical Report RM-28, 45 pp. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colorado.

Bell, Milo. 1973. Fisheries handbook of engineering requirements and biological criteria. Fisheries Engineering Research Program, Corps of Engineers, North Pacific Division, Portland, Oregon.

Bianchi, Donald R. 1963. "The Effects of sedimentation on egg survival of rainbow trout and cutthroat." Unpublished Master's Thesis, Montana State University, Bozeman.

Bishop, Clint. 1962. Effects of stream channel changes. Montana Fish and Game State Project Reports.

Bjornn et al. 1974. Sediment in streams and its effects on aquatic life. University of Idaho. Water Resources Research Institute, OWRP Project No. B-025-IDA. Moscow, Idaho. 47 pp.

Brown, G. W. and Kryiger, J. T. 1967. Changing water temperatures in small mountain streams. J. Soil Water Conser. 22:242-244.

Bugbee and Walter. 1972. Oil spill effects in South Dakota stream. Aviation Fuel.

Bury, Bruce. R. 1972. The effects of diesel fuel on a stream fauna. California Fish and Game. 58(4):291-295.

Campbell, H. J. 1954. The effect of siltation from gold dredging on the survival of rainbow trout and eyed eggs in Powder River Oregon. Oregon State Game Commission. 3 pp.

Carufel et al. 1973. Protecting fish habitat during forest road development. *Coordination guidelines for fish and wildlife habitats*. Number 7. San Francisco, California: USFS, California Region. 13 pp.

Chapman, D. W. 1962. Effects of logging upon fish resources of the West Coast. *J. For*. 60:533-7.

Cleary, R. F. 1956. Observations on factors affecting the smallmouth bass production in Iowa. *J. Wildl. Manage*. 20:353-359.

Cordone, A. J. and Kelley, D. W. 1961. The influence of inorganic sediments on the aquatic life of streams. *California Fish and Game*. 47(2):189-228.

Crabtree, Allen F., Basset, Charles E., Fisher, Lynn E. 1978. *The Impacts of pipeline construction on stream and wetland environments*. Michigan Public Service Commission, Dept. of Commerce. Lansing, Michigan.

Ellis, R. J. and Gowing, H. 1957. Relationship between food and supply and condition of wild brown trout (*Salmo trutta*) in a Michigan stream. *Journ. Limnology & Oceanography*. 7(4):299-308.

Elser, A. A. 1970. Fish populations of a trout stream in relation to major habitat zones and channel alterations. *Trans. Amer. Fish. Soc*. 97(4):389-397.

________, Marcoux, Ron. 1972. Effect of sediment on the aquatic environment. In: *Inventory of the waters of the project area*. Job Progress Report No. F-90R-19. Job No. I-a. Montana Department of Fish and Game.

Fisher, Jack. 1975. Correspondence to Dupont, from National Marine Fisheries, Anchorage, Alaska. November 26, 1975.

Fisher, S. G. and Likens, G. E. 1973. Energy flow in Bear Brook, New Hampshire: An integrative approach to stream ecosystem metabolism. *Ecol. Monogr*. 43:421-439.

Francisco, K. and Dinneford, W. B. 1977. Third interim report of the commercial fish - Technical Evaluation Study: *Salcha River*. JFWAT Special Report No. 17. JFWAT, Anchorage, Alaska.

Fredricksen, R. L. 1965. Sedimentation after logging construction in a small western Oregon watershed. *Federal Interagency Sedimentation Conference Proceedings*. U.S. Dept. of Agriculture, Misc. Publ. No. 970:56-59.

Gammon, James R. 1970. *The effect of inorganic sediment on stream biota*. Water Quality Office, E.P.A. Grant No. 18050 dwc. U.S. Government Printing Office. 113 pp.

Gebhards S. and Fisher, J. 1972. *Fish passage and culvert installations*. Idaho Fish and Game Department. 12 pp.

Gustason, J. 1977. *An Evaluation of low water crossings at fish streams along the Trans-Alaska Pipeline System*. JFWAT Special Report No. 16. 39 pp.

Haines, Terry A. and Butler, Robert L. 1969. Responses of yearling smallmouth bass (*Micropterus dolomieui*) to artificial shelter in a stream aquarium. *J. Fish. Res. Bd. Canada*. 26:21-31.

Hall, James D. and Lantz, Richard L. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. p. 355-375. In: T. G. Northcote (Ed) *Symposium on Salmon and Trout in Streams*. J. R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver.

Hartman, G. F. 1963. Observations on the behavior of juvenile brown trout in a stream aquarium during winter and spring. *J. Fish. Res. Bd. Canada*. 20:769-787.

Helmers, A. E. 1966. *Some effects of log jams and flooding in a salmon spawning stream*. North Forest Exp. Sta. USDA Forest Service. Res. Note NOR-14. 4 pp.

Herbert, D. W. M. and Merkens. J. C. 1961. The effect of suspended mineral solids on the survival of trout. *Int. J. Air Wat. Poll*. 5(1):46-55.

Hibbert, A. R. 1967. Forest treatment effects on water yield. In W. E. Sopper and H. W. Lull, *International symposium on forest hydrology*. pp. 527-543. Pergamon Press, New York.

Holton, George D. 1960. Report on proposed channel change on Prospect Creek, Sanders County in connection with construction of secondary highway FAS: No. 5-221(1). Montana Fish and Game State Project Reports.

Hubbs, Carl and Bailey, R. M. 1938. The smallmouth bass. *Cranbrook Inst. Sci. Bull. 10*. 92 pp.

________, and Rechnitzer, Andreas B. 1952. Report on experiments designed to determine effects of underwater explosions on fish life. *California Fish and Game*. 38(3) July 1952.

Hughes, W. 1976. Section 2 NSR, 20-25, July. JFWAT, Anchorage, Alaska.

Hunt, R. L. 1971. Responses of a brook trout population to habitat development in Lawrence Creek. *Tech. Bulletin 48, Wisc. Dept. of Nat. Res.,* Madison.

________. 1975. Food relations and behavior of salmonid fishes. p. 137-151. In Coupling of Land and Water Systems. *Ecol. Studies Vol. 10,* A. D. Hasler, ed. 1975. New York, NY.

Hynes, H. B. N. 1960. *The Biology of polluted waters*. Liverpool Univ. Press. 202 pp.

_______. 1970. The ecology of running waters. University of Toronto Press, Waterloo, Ontario, Canada. 555 pp.

Kalleberg, H. 1958. Observations in a stream tank of territoriality and competition in juvenile salmon and trout. Rep. Inst. Freshwater Res., Drotthingholm. 39:55-98.

Kavanaugh, M. and Townsend, A. 1977. Construction-related oil spills along the Trans-Alaska Pipeline. JFWAT Special Report No. 15. 16 pp.

Kay, C. E. September 21, 1976 memo to Al Carson, JFWAT Supervisor. Environmental and Fisheries Problems Associated with the Haul Road. 5 pp. 28 photographs, 3 figures, 3 appendixes.

Kernofle, D. 1975. Trip report--turbidity observations in the Little Tonsina River. U.S.F.S., Anchorage (May 14,) 4 pp.

Koski, K. Victor. 1966. The survival of coho salmon (Oncorhynchus Kisutch) from egg deposition to emergence in three Oregon coastal streams. M.S. thesis. Oregon State University, Corvallis. 84 pp.

Leopold, L. B. and Langbein, W. B. 1966. River meanders. Scien. Am. 214:60-70.

Lewis, Stephen L. 1969. Physical Factors Influencing Fish Populations in Pools of a Trout Stream. Trans. Am. Fish Soc. 98(1):14-19.

MacPhee, C. and Watts, F. J. 1975. Swimming performance of arctic grayling in highway culverts. Progress Report to the U.S. Fish and Wildlife Service, Anchorage, Alaska. University of Idaho, Moscow, Idaho. 39 pp.

McCauley, Rita N. 1964. The biological effects of oil pollution in a river. Dissertation Cornell University.

McCrimmon, H. R. 1954. Stream studies on planted Atlantic salmon. J. Fish. Res. Bd. Canada. 11:362-403.

McKinley, W. R. and Webb, R. D. 1956. A proposed correction of migratory fish problems at box culverts. Washington Department of Fisheries. Fisheries Research Papers. 1(4):33-45.

McNeil, W. J. 1966. Effects of the spawning bed environment on reproduction of pink and chum salmon. U.S. Fish and Wildlife. Serv. Fish Bull. 65:495-523.

Megahan, W. F. and Kidd, W. J. 1972. Effects of logging and logging roads on erosion and sediment deposition from steep terrain. J. For. 70:136-141.

Munoy, R. J. 1962. Life history of the yellow perch (Perca flavesceus) in in esturine waters of the Severn River, a tributary of Chesapeake Bay, Maryland. Chesapeake Sci. 3:143-159.

Narver, David W. 1970. Effects of logging debris on fish production. In Proceedings of a symposium, forest land uses and stream environment. pp. 100-111.

Northern Tier Pipeline Company 1978. Northern Tier pipeline: description of the proposed action. Submitted to the Bureau of Land Management of the USDI. May 12, 1978.

Peters, J. C. 1967. Effects on a trout stream of sediment from agricultural practices. J. Wildl. Mgmt. 31(4):805-812.

Phillips, R. W. 1970. Effects of sediment on the gravel environment and fish production. Forest land uses and stream environment. Corvallis: Oregon State University. pp. 64-74.

Rice, Stanley D., Adam Moles, D. and Short, Jeffrey W. 1975. The effect of Prudhoe Bay crude oil on survival and growth of eggs, alevins, and fry of pink salmon (Oncorhynchus gorbuscha). In: 1975 Conference of prevention and control of oil pollution. American Petroleum Institute.

Rothacher, Jack. 1970. Increases in water yield following clear-cut logging in the pacific northwest. Water Resources Res. 6:653-658.

Saunders, J. W. and Smith, M. W. 1965. Changes in a stream population of trout associated with increased silt. J. Fish. Res. Bd. Canada. 22(2):395-404.

Sandmeyer, R. H. January 1979. Letters from R. H. Sandmeyer of Butler and Associates, Inc. to Dave Janis, Energy Division, Montana Department of Natural Resources and Conservation, Helena, Montana.

Schaumburg, F. D. and Atkinson, S., M.S. 1970. BOD_5 and toxicity associated with log leachates. Presented in West. Div. Am. Fish. Soc., July 13-16, 1970, Victoria, British Columbia.

Schultz, Donald and Tebo, L. B. 1975. Boone Creek oil spill. Conference on prevention and control of oil pollution. p. 583. American Petroleum Institute.

Scott, W. B. and Crossman, E. J. 1973. Freshwater Fishes of Canada. Bulletin 184, Fisheries Research Board of Canada, Ottawa.

Shallock, Eldor W. 1979. Preliminary results and conclusions derived from the Chatanika River-Alyeska oil pipeline crossing project. Personal Communication and rough draft report. March, 1979. E.P.A., Arctic Environmental Research Laboratory, College, Alaska.

Sloan, C. E. 1975. Trip report--turbidity observations in the Tonsina River. USFS, Anchorage, (April 14). 4 pp.

Smith, Osgood R. 1939. Placer mining silt and its relation to salmon and trout on the Pacific coast. Trans. Amer. Fish. Soc. 69:225-230.

Snow, N. B. *et al*. 1975. Experimental oil spills on northwestern arctic stream. *Canadian Task Force, North Oil Developmental Environmental Society Commission.* vol. III.

________, and Rosenberg, D. M. 1975. Experimental oil spills on Mackenzie delta lakes. I. Effect of norman wells crude oil on lake 4. In: Ecological studies of aquatic systems in the Mackenzie-Porcupine drainages in relation to proposed pipeline and highway developments. ed. G. J. Brunskill. Canada Task Force N. Oil Dev. *Env. Soc. Comm.* vol. III.

________, and Scott, B. F. 1975. The effect and fate of crude oil spilt on two arctic lakes. *Conference on Prevention and Control of Oil Pollution*. p. 527. American Petroleum Institute.

Surber, E. W., English, J. M. and McDermott, G. N. 1965. Tainting of fish by outboard motor exhaust wastes as related to gas and oil consumption. pp. 170-176. In: *Biological problems in water pollution*, 3rd seminar, Aug. 13-17, 1962. U.S. Department of HEW. Pub. 999-WP-25.

Swanston, D. N. 1970. Principle soil movement processes influenced by road building, logging, and fire. In *Forest land uses and stream environment*. Corvallis: Oregon State University.

Tebo, L. B. 1955. Effects of siltation resulting from improper logging on the bottom fauna of a small trout stream in the southern Appalachians. *Progressive Fish-Culturist*. 17(2):64-70.

U.S. Department of the Interior. 1979. Bureau of Land Management draft environmental impact statement. *Crude oil transportation system: Port Angeles, Washington, to Clearbrook, Minnesota* (as proposed by the Northern Tier Pipeline Company). Portland, Oregon.

U.S. Department of Transportation. 1978. Summary of liquid pipeline accidents as reported on USDOT form 7000-1: from Jan. 1, 1977 through Dec. 31, 1977.

Townsend, A. October 21-29, 1975. JFWAT TAPS Section 3 Surveillance Report. JFWAT, Anchorage, Alaska.

Wallen, I. Eugene. 1951. The direct effect of turbidity on fishes. *Bull. Okla. Agri. and Mech. Col.*, Arts and Sci. Studies, Biol. Ser. No 2, Vol. 48 No. 2. 27 pp.

Watts, F. J. 1974. *Design of culvert fishways*. Supplement to Technical Completion report for U.S. Department of the Interior, Office of Water Resources Research, project A-027-IDA.

White, R. J. 1973. Stream channel suitability for cold water fish. In *Proc. 28th annual meeting soil conservation society of America*. pp. 61-79.

________. 1975. In-stream management for wild trout. In W. King (Ed.) *Proc. of wild trout management symp.*, Yellowstone Park, Sept. 24-25, 1974, Trout Unlimited. 103 pp.

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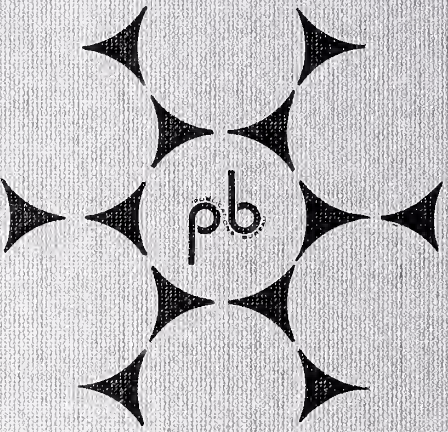

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